In: Markgraf. u. Küntscher a (U.S. Nav. Techn. Unit) 1947, 1: 2:

Germany (Territory under Allied Occupation, 1945-
U.S.Zone) ~~Office of Military Government.~~
Office of the Naval Advisor.

PROJECT II FOLIO II

MARKNAGELUNG
NACH KUENTSCHER
(MARROW NAILING--MEDULLARY NAILINT)

Part II
Symposium

Translation prepared by:

U.S.Naval Technical Unit, Europe,
(Medical Section) Office of the
Naval Advisor, Office of the Military
Government (U.S.).

INDEX

THE IMPORTANCE OF A STABILE OSTEOSYNTHESIS TO A SUCCESSFUL MARROW NAILING

by

Priv. Doz. Dr. med. Richard MAATZ, Kiel

Translation prepared by:

U. S. Naval Technical Unit, Europe, (Med.Sect.)
Office of Naval Advisor
Office of Military Government (U.S.)

The success of marrow-nailing depends on a "stabile osteosythesis" being achieved. Only if the fragments are firmly connected by the nail can we do without an additional plaster cast. Only then can we expect a rapid bony union in good position and only then are we justified to nail even compound fractures, to correct the malposition of older suppurating gun-shot fractures and to treat them with the nail. If a stabile union of the fragments is not achieved by the nail one may expect displacement, delay of union or even non-union of the fragments. Compound fractures will show severe suppuration, and gun-shot fractures nailed in a suppurating state will show again and again a flare up of the infection.

It may be easy, it may be difficult or even impossible to attain a "stabile osteosynthesis" by means of the KUENTSCHER nail. In general the result can be foreseen and this alone will have to indicate the treatment to be chosen. The suitability of a fracture for treatment by nailing cannot be judged by the length of its shortest fragment. Several factors are of decisive importance: Site and shape of the fracture, shape of the medullary cavity, the place where the nail is to be introduced, the shape of the nail and its stability, and, finally a possible lack of firmness of the bone may require most careful consideration.

Considerable experience is necessary to judge each of these factors. The fundamental rules are simple. I have described them 1942 in the " Formschluessigkeit bei der Marknagelung." (see this collection of translations).

Moreover I want to report on new forms of nails today. They have arisen from the endeavor to increase the number of stabile osteosyntheses. For years the nails have proven to be efficient. They make a successful nailing possible even in those cases in which the nails described by KUENTSCHER will fail. I have to refuse the reproach of complicating a "simple" method. It is not most important that it is easy to drive in the nail. The point is to accomplish a successful nailing. Besides, the spreading nails have remained plain and simple and reliable in their shape as must be demanded of so large a foreign body in the marrow cavity.

As stated by KUENTSCHER the marrow nail should unite the fragments with the same elastic power as the carpenter's nail unites two pieces of timber. The marrow nail, which in its cross section is elastic, is slightly compressed when driven into the bone cylinder. Consequently a considerable power of friction will arise between the nail and the bone. But these favorable conditions are to be found only in the long bones with an extensive constant cross section of both fragments when a straight nail is used. (Ill. 1) Under these conditions it does not matter how the fracture is shaped if only at any place one part of the one fragment may be set upon the other so that a displacement is impossible.

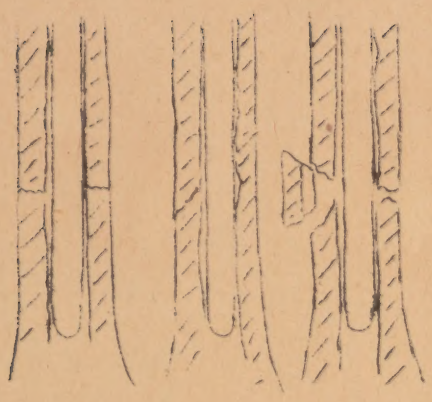


Illustration 1

Most favorable mechanical conditions. Equal cross section of both marrow cavities and straight nail.

If larger pieces of bone have broken out the nail then is no longer encircled and supported by the bone and has to stand for itself against all forces threatening to bend it. This will demand a considerable stability of the nail and that is why we can find these most favorable conditions only in the thigh where the strong straight nail is introduced into the tubular cavity of the bone the cross section of which does not vary.

A disturbance of the growth of callus never has been complained of under these conditions. The sometimes remarkably trivial formation of callus shown by the roentgenogram is due to the ideal reduction and to the absolute immobilization of the fragments.

The conditions become much more unfavorable if the cross section of the medullary cavity is not constant. The femur too shows in its upper and lower end a marked enlargement of the cavity. In its distal end this begins higher the younger the individual. If the fracture is situated between the place where the nail is to be driven in and the smallest cross section of the cavity there will be no great difficulties. For these cases I have recommended the "conical nail" for subtrochanteric fractures as shown in Ill. 2.

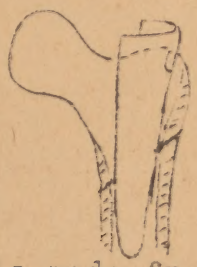


Illustration 2

Conical nail for subtrochanteric fractures.

This nail is made from a steel plate thinner than for the usual nail. It has a broad surface bearing on the spongiosa of the trochanteric area and is well adapted to the narrowing marrow cavity. Though at this place a delay of union is of extremely rare occurrence it is still suitable to use since only this nail is able to prevent the fracture from rotary displacement, and also to avoid an undesirable shortening of the bone in oblique fractures.

The conditions are much more unfavorable if the fracture is situated beyond the most narrow part of the medullary cavity. Here the nail becomes a bolt. In the distal fragment there will never be sufficient friction between the nail and the bone. In general if there is a plain transverse fracture (Ill. 3), the fragments will be rendered resistent to angulation by the great force of the muscles pressing them firmly together. By the nail the fragments are protected from slipping to the side and so the fracture can only be angulated with as much difficulty as two cylinders standing upon each other which are pressed together by great powers. (Ill. 4).

Illustration 3

The nail as a bolt.

Illustration 4

Cylinders standing upon each other and pressed together are rather resistant against angulation.

But the fracture treated in the above manner is protected against rotary displacement. Therefore I have utilized the fact that the cross section of the cavity in the distal part has an oval shape and have recommended a double nail, spreading at least in one plane, for suitable cases (Ill. 5). We have not yet produced an entirely satisfactory spreading nail for the thigh. We are occupied with further experiments. If we have a dentated fracture under otherwise the same conditions as above (Ill. 6) the osteosynthesis may be stable because now the fragments are protected against rotary displacement by the principle of the cog wheel (Hirth-teeth). (Ill. 7).

The conditions for an oblique fracture at once are considerably more favorable under what are otherwise the same circumstances. The surfaces of the fragments slide along each other until nail and bone are firmly fixed. The resulting slight shortening in general is of no importance but the fracture is made resistant against bending and angulation by means of the nail. Due to the obliquity of the line of fracture it is also protected against rotary displacement since rotation at the same time means a lengthening of the bone and this would have to act against

Illustration 5

Spreading nail for the thigh. Screw showing in X-ray was left in the wound at the time of removal of a Lane plate done in another clinic.

Illustration 6

This bolted fracture is protected against rotary displacement after the principle of the Hirth-teeth.

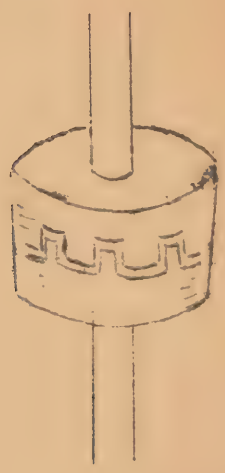


Illustration 7

Hirth-teeth (screw against rotation).

the tonicity of the muscles and the "statische Belastung" (other forces of physiological function) (Ill. 8)

Illustration 8

Rotation of the fragments of an oblique fracture is prevented because of the associated lengthening.

The disadvantage of the bolting in a medullary cavity enlarging in its distal end will only become disastrous when the bone cylinders are not standing firmly upon each other due to the breaking off of a third fragment or of several pieces of bone. For they will be liable to tilting and the fracture will be angulated (Ill. 9)

Illustration 9

Caused by a third fragment the bolted fracture has angulated.

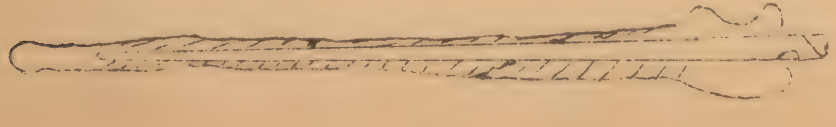
In general the fragments are wedged together thereafter in such a way that the growth of callus is not disturbed. The extent of the displacement ad axim is of decisive importance for the final result, namely the shape of the bone after healing. If there is a considerable tilting of the fragments an actual delay of the growth of callus may occur and even a retardation of bony union, as shown in Ill. 10.

Illustration 10

Delayed frowth of callus in a bolted fracture of the thigh. State 6 months after nailing. Patient treated later by spreading nail Ill. 5.

For months the patient complained of a "dangling" in the fracture and had therefore for a long time been required to wear a full length plaster splint. This bolted fracture had not been stabilised by the nail.

All authors agree in the opinion that the conditions for nailing are by far the most favorable in the thigh. Here we have the long and firm bone cylinder, the cross section of its cavity does not vary throughout a considerable length, we have especially strong muscles pressing the fragments together and we can introduce a strong straight nail. In addition to the femur only the ulna permits the use of a straight nail. But its cavity being rather narrow in the middle and often curved in compels us to use a nail of special shape if we want to avoid an insufficiency of the nail with resulting delay of union or even severe malposition of the fracture. Fracture of the nail has most often occurred in the ulna. We have seen several cases in which the nail was bent almost to a right angle. This was associated with fractures situated near the elbow joint. Here it is absolutely necessary to select a nail as strong as possible and in adaptation to the shape of the bone it must be conical. Its broader part does not lie chiefly in the marrow cavity but in the spongiosa and this is why its broad shape is so desirable (Ill. 11)



Ill. 11

The nail for the ulna, flared at its head end.

None of the fresh fractures of the ulna, either compound or simple, which have been treated with such a nail have shown a disturbed growth of callus or a subsequent displacement of the fragments. But if we want to treat a pseudarthrosis of the ulna we must use the marrow spring in addition to the nail. The operative treatment of a pseudarthrosis is of necessity associated with a shortening of the bone due to the necessary freshening of the fragments. In general the power of the muscles to press both fragments against each other is very poor in the arm so that a separation and a gap between the fragments is not unusual. Since this is observed more frequently after the operation upon a pseudarthrosis and the formation of callus in the forearm not being suitable for bridging over a gap between the fragments, as is well known, non-union does occur far too easily. Ill. 12 shows one example out of a number.

Illustration 12

Pseudarthrosis of the ulna after nailing (pseudarthrosis of radius was intentionally permitted to persist).

By the additional use of the marrow-spring, the gap between the fragments is avoided and the fracture or pseudarthrosis will heal.

This marrow spring at the proximal end is fastened to the nail and at the distal end to the corticalis by a special hook (Ill. 13). The conical shape of the nail prevents its intruding more profoundly into the bone so that the spring remains constantly under tension.

Illustration 13
Nail for the ulna with marrow spring.

Illustration 14a

Pseudarthrosis of the ulna, Lane plate in position.

Illustration 14b

State after nailing the bones with shortening of the radius. The marrow spring in the ulna is pressing the fragments together.

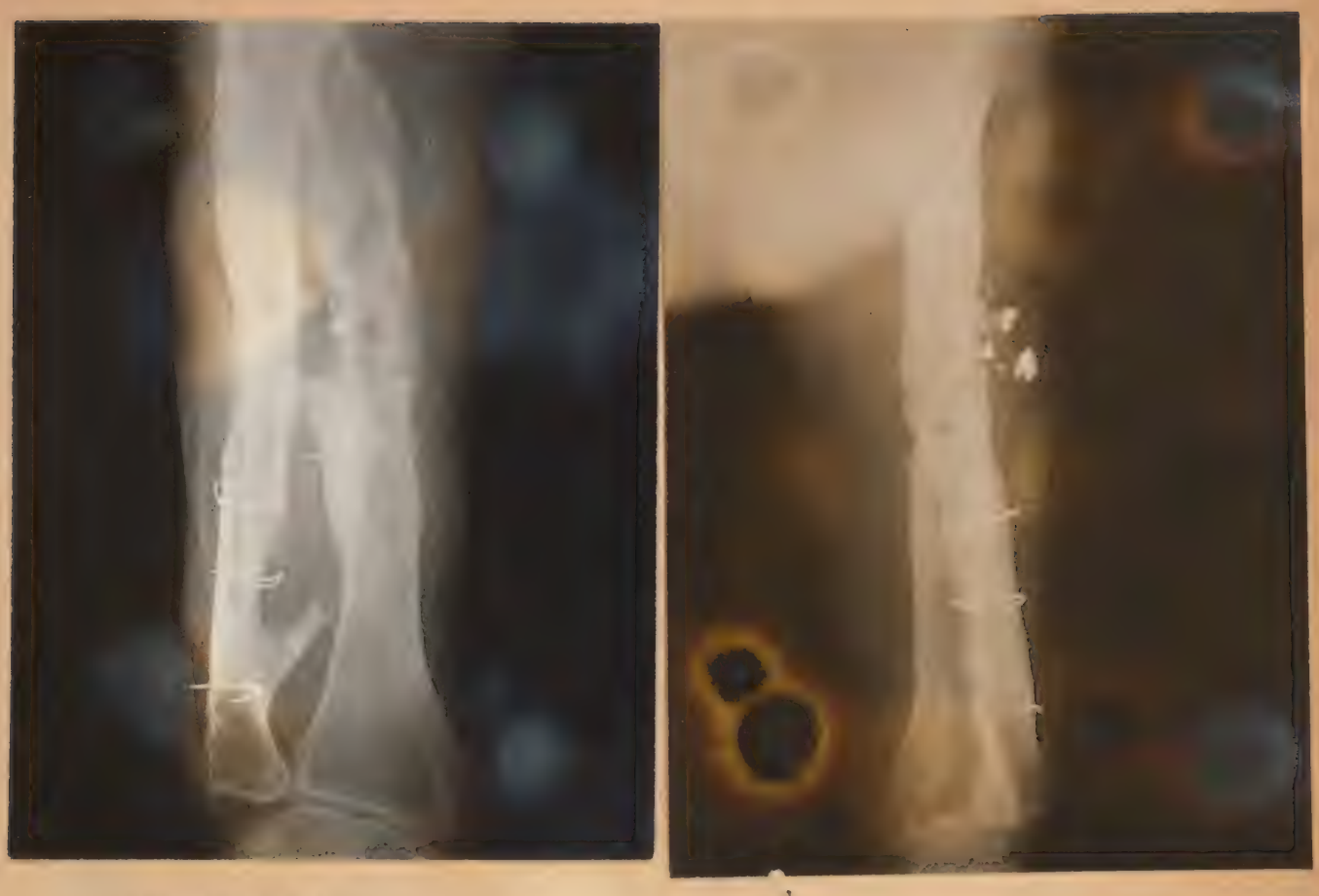


Illustration 14 c
(1 & 2)

Bony union after
three months

If we are forced by the shape of the bone and the place where the nail has to be introduced to use curved nails which consequently are elastic, we are confronted with new mechanical conditions. If we drive the nail from laterally and below into the tube of a bone enlarging in its upper part, as for instance the humerus, we can never expect a solid "Formschluessigkeit" (a term indicating the exactness of contact between two objects). (Ill. 15)

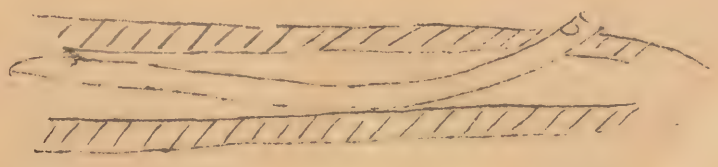


Illustration 15
The laterally introduced nail must have a smaller cross section than the marrow cavity.

During the first days we generally observe a jamming of the curved nail in the marrow cavity, but all too often this will be so unreliable that very soon the fragments separate. The result in a gap at the fracture site, which in a closed fracture will lead to a delay in the development of callus while in a suppurating fracture will cause a pseudarthrosis. If a pseudarthrosis is treated in this way, it will be the reason for its further existence (Ill. 16-19).

Illustration 16

Delay of the formation of callus in a closed fracture of the upper arm which has been nailed.
Pat. K. 2 months after nailing.

Illustration 17

Pseudarthrosis after an open fracture nailed and infected.
Pat. Schw. 4 months after operation.

As a result of the forces of weight bearing not acting and the tonicity of the muscles being relatively slight, distraction of the fragments is more apt to occur in a fracture of the upper arm than in fractures of the lower limb because the nail itself may act in such a way as to interfere with the close apposition of the fragments. A blocking effect caused by the nail may easily occur in the upper arm, since here we have peculiar mechanical conditions. The point of the nail may very easily become stuck in the marrow cavity which thins out in its distal part. The power pressing the fragments against one another are slight (tonicity of the muscles) and moreover the weight of the arm acts against them. If once a separation of the fracture has occurred these powers are no longer able to overcome the

Illustration 18

Persisting pseudarthrosis 2 months after freshening and nailing, Pat. L.

Illustration 19

Persisting pseudarthrosis after nailing and wire suture in the upper arm. Pat. K.

friction between the rough inner surface of the bone and the necessarily curved nail. In the lower extremity the tonicity of the muscles is much stronger, there is the weight of the body when standing, and the medullary cavity is narrow at the distal end of the tibia, as well as of the femur, preventing the point of the nail from running into the rough interior layer of the bone, all of which are factors explaining why we do not observe the blocking effect of the nail in the lower limb as in the upper limb. In addition since the nail must be elastic slight tilting motion in the fracture with resulting delay of union or non-union may occur.

All those disadvantages will occur less easily, the more oblique the line of fracture. But since the nailing is most urgently indicated for the plain transverse fracture of the upper arm, the reduction of which is maintained only with difficulty, we must try to decrease the above disadvantages. If there is a closed fracture we will succeed most often if we use a very small diameter nail which can never cause a blocking effect. If the patient, supporting the arm in a sling, complains of pain in the fracture during the first days after the operation, a splint in abduction will give sufficient additional stability.

Illustration 20

Blocking effect of the nail in the upper arm with seriously delayed formation of callus. Pat. J.

For the pseudarthrosis and especially the pseudarthrosis with a loss of substance, the use of the marrow-spring is urgently indicated. I shall report on this at another place. Here I want only to give an example. (Ill. 21).

Illustration 21

Gunshot fracture of the upper arm which has not united in spite of nailing. The [illegible] fracture.

a2

a3

Illustration 21
Gunshot fracture of the upper arm which has not united in spite of nailing.
2) the fresh nailed fracture
3) pseudarthrosis 4 months afterwards.

Illustration 21_b

Same case, bony union 3 months after fresh [illegible] and insertion [illegible] marrow spring.

a

b c

d

Illustration 22

Pat. W.

a,b & c - Lengthening of a nail which is too short in the radius, with seriously delayed formation of callus

d - only when a long nail was used did the patient get rid of the pain and bony union was achieved.

As to the formation of callus in general the same is to be said for the radius as for the ulna. The bone will only very seldom succeed in bridging over a loss of substance by means of callus, this is why after osteotomies and operations upon pseudarthroses the close apposition of both fragments achieved by the narrow spring is so important. In general in the forearm this will always be achieved sufficiently, by using the spring in the ulna alone. The conditions in the tibia are very peculiar. This bone expands at its upper and lower end and has a real waist in the middle. The elastic nail has to be introduced from the side.

If the fracture is situated at the most narrow part of the marrow cavity a real nailing can be achieved (Ill. 23). But if a third fragment has broken out the fracture is liable to angulation. In this case the osteosynthesis is no longer a stabile one. There will be tilting movements in the fracture with a delay of the formation of callus as a result.

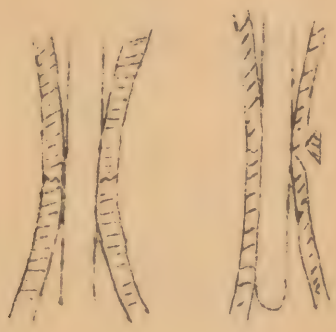


Illustration 23

Favorable conditions for the nailing of the tibia

Illustration 24

An insufficient stabilization of the tibia consequently causes a delay of the formation of callus. (4 months after nailing.)

But if the fracture is located in the area of greater cross section of the marrow cavity regardless of whether it is in the upper or lower end, this may lead the more readily to unsatisfactory dislocaements. (Ill. 25) Even in the middle of the tibia we observe, under otherwise favorable conditions, a delay of union when too thin a nail has been used. We must not forget that the laterally introduced nail has considerable elasticity. Thus when a thin nail is used in a transverse fracture of the tibia at its most narrow part shearing effects are possible (Ill. 26).

a b

Illustration 25a & b

Axial displacement of the nailed fracture located in the distal part of the tibia. Delay of the development of callus. Fit. Sch., 4 months after the nailing.

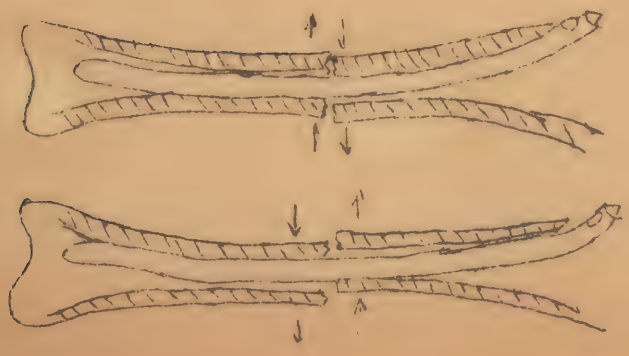


Illustration 26

Shearing effect in a plain transverse fracture of the tibia caused by too thin a nail.

If the fracture of the tibia is bearing weight the nail will bend a bit and as it does not fill out the marrow cavity entirely, the lower fragment will slide past the upper one to the front side whilst as soon as the weight is taken away the nail will straighten and the fragments will move in the opposite direction.

So it is no wonder that under these unfavorable mechanical circumstances an insufficient stabilization of the fracture and consequently a delay of union is to be expected rather frequently in the lower leg. That is why in the University Hospital, Kiel when using the simple double nail for the lower leg (129 cases) we have had to treat 50% of the fractures with an additional plaster cast. EHRLICH has begun to provide each nailed fracture of the lower leg with a plaster cast on principle and BOEHLER refuses to nail the pseudarthrosis of the lower leg because of the delay in the formation of callus for the same reason.

That is why in the lower leg I use spreading nails. Such nails must be of plain shape and they must not be difficult to introduce. Both conditions are achieved and clinical experience proves their decisive superiority so that to-day I treat every fracture of the tibia with this nail. Of the 47 fractures treated with this nail only 3 had to have an additional plaster dressing. Delay of union has occurred in no case.

The rotating spread nail (Ill. 27 and 28) consists of the usual exterior nail as described by KUNTSCHER and of an interior nail which is round and solid, apart from two lateral groves for drainage of blood and marrow. It is curved in the shape of an S, has a transverse notch at the front near the head to facilitate removal, a small drilled hole for countertraction when the outer nail is being inserted, and on its end a transverse groove (like the head of a screw) which makes it possible to rotate the nail round its longitudinal axis while it is being driven into the bone.

Ill. 27

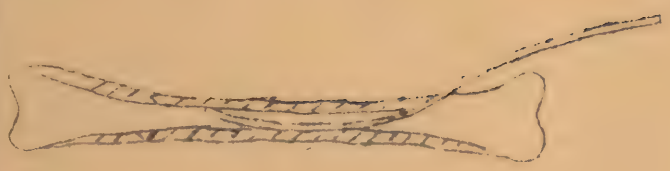
Rotating spread-nail for the tibia.

At first the inner nail is introduced judiciously corresponding to its curving (Ill. 29a) When its point has passed the most narrow part of the marrow cavity the nail is finally driven in by striking on a short screw driver set into the transverse notch, at the same time rotating it through 180°.

Previously a wire has to be drawn through the small drilled hole which later on is used to prevent the inner nail being driven further into the marrow-room as the outer nail is introduced.

Illustration 28

Rotating spread-nail in the tibia with a transverse fracture below the middle.



a

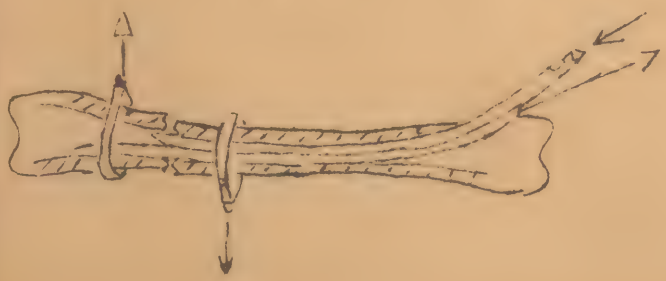


Illustration 27

Rotating spread nail for the tibia to be used for transverse and short oblique fractures.

a. introduction of the inner nail shortly before the rotation.

b. introduction of the outer nail with appropriate displacement of the fragments, the inner nail being protected, by countertraction, from being taken out by the outer nail.

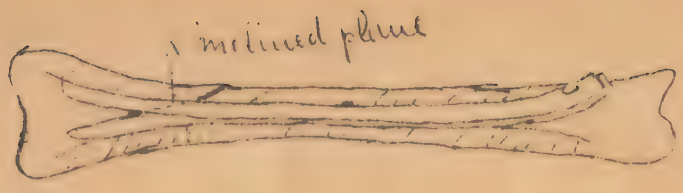


Illustration 30

Spreading nail with inclined plane for the tibia - to be used for longer oblique fractures.

When the outer nail is driven in later a momentary appropriate displacement of the fragments may be necessary by lateral traction in order to render the introduction of this nail into the distal part of the marrow cavity possible.

This nail has a rather great elasticity due to this spreading system. It is therefore only suitable for the transverse and short oblique fractures.

On the contrary the spread legs of the spreading nail with the inclined plane are nearly inflexible. Therefore this nail is to be used for longer oblique fractures and especially for fractures where pieces of bone have been broken out demanding a nail of great stability (Ill. 30).

The spreading of the two nails is effected by a wedge of steel fastened to the exterior nail at the appropriate place. It is evident that this pair of nails will get a firm hold in the bone and consequently will stabilize all fractures which are not located too far distally as the spreading of the nail is produced only by the counter-pressure of the bone cylinder.

Here of course the outer nail is to be introduced first and during the introduction of the interior nail and appropriate displacement of the fragments may be necessary lest the second (inner) nail will miss the medullary cavity of the distal fragment (Ill. 31).

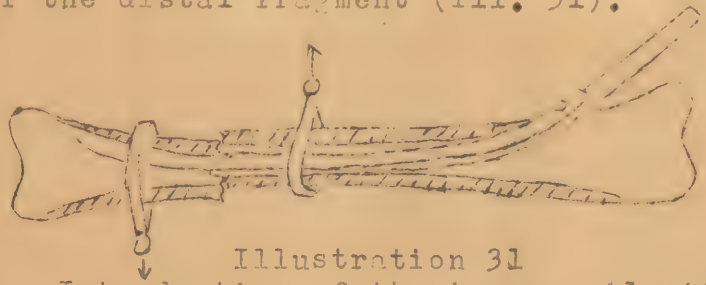


Illustration 31

Introduction of the inner nail with the necessary momentary dislocation of the fragments.

Here too counter-traction prevents the nail introduced first from intruding too far into the medullary cavity. The inclined plane must be situated at the very place where the cross section of the marrow-room is the same as the cross section of both nails together.

Illustration 32 a1 + 2

Comminuted fracture of the lower leg with spreading and with inclined plane, very satisfactory position and undisturbed formation of callus.
a) Pat. R. Triangular fragment is seen only in view of nailed fracture
b) Pat. St.

b_1

b_2

Illustration $32_{b1 \& 2}$

Illustration $32_{b3 \& 4}$

L I T E R A T U R

BOEHLER ..... Zschr. orthop.u.Grenzgeb. 75. Bd. H.4. 1944

" ..... Orthop. Kongress Wien 1944

KUENTSCHER .... Klin. Wschr. 1940 I/II

" ..... Zbl. Chir. 1940 1145

" ..... " " 1941 .1

" ..... Chir. 1942 H.6

" .... Zbl. Chir. 1942 1837

KUENTSCHER and MAATZ.. Die Tech. d. Marknagel. Leipzig 1944

MAATZ .... Chir. 1943 H.9

" .... Zbl. Chir. 1943 1260 & 1641

" .... Orthop. Kongress Wien 1944

" .... Chir. Kongress Buren/Westf. 1946

From the Surgical Clinic of the University Kiel
Director Representative: Professor Dr. ANSCHUETZ

F U R T H E R E X P E R I E N C E S W I T H T H E M A R R O W - N A I L I N G - M E T H O D O F K U E N T S C H E R

at the Surgical Clinic of the University K i e l.

by

Private Dozent Dr. med. Heinz G r i e s s m a n n
Senior Physician of the clinic

and

Assistant Dr. med. Wilhelm S c h u e t t e m e y e r
of the clinic

To Professor A n s c h u e t z at his 76th birthday.

Translation prepared by:

U.S.Naval Technical Unit, Europe, (Medical Section)
Office of the Naval Advisor
Office of the Military Government (U.S.)

This report is about the further experiences on the marrow-nailing method by KUENTSCHER made at the surgical clinic of the University of Kiel. These marrow-nailings were done during the period between 1st Jan 1944 and 1st May 1946.

The technic itself will not be discussed in this report, except that when another technique than usual was used for special reasons it will be mentioned in the appropriate place. For all details concerning the general technique we refer to the publications of KUENTSCHER, MAATZ and FISCHER.

During this period 155 marrow-nailings were performed. These 155 marrow-nailings include 49 of the femur, 64 of the leg, 14 of the upper arm, 28 of the forearm (see table 1). Three cases treated by MAATZ following a new technique are not included as MAATZ will report on this matter elsewhere.

Table 1

	Lower legs	Thigh	Arms above the elbow	Forearms	Total
Simple fractures	46	35	10	16	107
Compound fractures	15	7	-	2	24
Pseudarthroses	2	-	2	10	14
Osteotomies	-	2	-	-	2
Metastases	-	4	1	-	5
Late nailings in the presence of purulent infections	1	1	1	-	3
Total	64	49	14	28	155

I. MARROW-NAILING OF THE LOWER LEG.

Altogether 64 fractures were treated by means of the marrow-nail of KUENTSCHER. All fractures of the leg are nailed in so far as they are suitable for nailing according to the directions of the book of KUENTSCHER and MAATZ.

In cases of children the nailing of legs is made only if the fracture cannot be fixed in any other way. The indication in children is much less frequent because of possible disturbances of growth and a greater danger of infections (osteo-myelitis).

It is only in a very few cases that great and lasting disturbances of the joints of children have been observed, when the splint method was used; thus in these cases the great advantage of the marrow nailing method is not very important, namely the possibility to move the limbs quite early after the operation.

One boy was nailed, who was very strong for 14 years, and whose fracture was not cured though several attempts had been made at another hospital. The remaining cases included individuals between 18 and 81 years old of both sexes.

All fractures of the leg were nailed as early as possible after the arrival of the patient at the clinic. If the nailing could not be performed immediately because of shock or severe additional injuries or on account of nails not being available or for similar technical reasons, the patients were at first provided with traction-apparatus or wire extension in suitable splints. If the nailing could not be performed for the same reasons in cases of compound fractures, the nailing was usually done after wound had closed. The 64 nailed fractures of the leg include 46 simple fractures, 15 compound fractures, 2 pseudarthroses, and 1 late nailing in the presence of a purulent infection.

a) Simple Fractures.

42 simple fractures of the leg were nailed immediately after the arrival of the patient at the clinic, 4 at a later time. Two of these last 4 cases were brought to our clinic not before 8 and 21 days after the accident. The third patient was not nailed early because of luxation of the tarsus and its fracture, and the fourth patient because of an additional fracture of the femur and severe collapse. The 46 simple fractures included 29 fractures of the lower third of the leg, 13 fractures at the middle, and 4 double fractures.

Table 2.

Simple fractures in the lower leg.

46

Site and kind of the fracture.

Medium third 13						Lower third 29						Double fractures 4		
transverse fracture 9			oblique fracture 4			transverse fracture 8			oblique fracture 21			double fracture 4		
double nail	inclined plane	turn-spread	double nail	inclined plane	turn-spread	double nail	inclined plane	turn-spread	double nail	inclined plane	turn-spread	double nail	inclined plane	spread nail
7	-	2	4	-	-	5	1	2	3	14	4	3	1	-
⊿ ⊖	⊿ ⊖	⊿ ⊖	⊿ ⊖	⊿ ⊖	⊿ ⊖	⊿ ⊖	⊿ ⊖	⊿ ⊖	⊿ ⊖	⊿ ⊖	⊿ ⊖	⊿ ⊖	⊿ ⊖	⊿ ⊖
6 1	- -	2 -	2 2	- -	- -	- 5	1 -	2 -	2 1	14 -	3 1	2 1	1 -	- -

Legend: ⊿ stabile
⊖ not stabile

The 46 leg-fractures are indicated in table 2, showing their number, location and the kind of fracture. This arrangement is regarded as important to answer the question, whether different shapes of nails are absolutely necessary to obtain a stabile osteosynthesis in any case.

This table shows beyond doubt that the double nail regularly leads to a stabile osteosynthesis in transverse fractures of the middle third (Ill. 1).

In 6 of the 7 fractures in the middle, stability was obtained. In cases of transverse fractures in the lower third treated with a double nail, adequate stability could not be obtained, not even in one case. It was always necessary to provide the fracture with an additional fixation bandage. It is apparent that the spread nails can be used to obtain good fixation in transverse fractures in the middle of the leg (Ill. 2)

In cases of oblique fractures in the middle of the leg the double nail does not always provide absolute stability, as can be learned from the tables. The three transverse fractures of the lower third of the tibia treated with spread nails were stable (Ill.3

The oblique fractures of the lower third of the leg, which are the most frequent and most difficult to treat, may in some cases be provided with a rigid system of spreading, and when this can be accomplished it is not necessary to apply additional fixation (Ill.4

This condition will be obtained most successfully with the spread nail with inclined plane. The turn-spread nail is more of a spring-elastic system, which is sufficient in transverse fractures in the lower third of the leg, as at that place there is little danger that the fracture may be dislocated. All 14 oblique fractures in the lower third treated with a nail with inclined plane obtained a stabile osteosynthesis in every case, as the table shows. Both kinds of spread nails are recommended by MAATZ. The double- and turn-spread nails failed in one case each of oblique fractures in the lower third. We want especially to point out here, that the location of the inclined plane has to be calculated as well as the diameter of the nail according to the kind of fracture, as it is reported by MAATZ.

In case of a comminuted fracture the middle fragment has to be "strung" (as pearls are strung) and usually only a double nail can be used. In that way 3 of the 4 comminuted fractures could be nailed and a stabile osteosynthesis be obtained. But even if no stability can be obtained the marrow-nailing method is an advantage in these fractures, as no considerable dislocations will occur in any case.

All these facts hitherto reported prove that the double nail can be used only in simple transverse fractures in the middle, if it also is situated at the narrowest part of the marrow cavity, and that in all other cases the turn-spread nail or the spread-nail with inclined plane has to be used according to the kind of fracture.

We are aware that this limitation is a disadvantage in that a hospital, willing to perform the marrow-nailings according to these proven points of view, has to have in stock not only spread-nails of different sizes, but among the spread-nails those with inclined plane as well, and which have the inclined plane attached at different locations. Generally it is sufficient to use nails with the inclined plane fixed on them at distances of 5 cms, 6 cms, or 7 cms from the tip of the nail.

But we regard even the simple nailing with the double nail as having considerable advantages over other methods of treatment: 1. because of the impossibility of any great dislocation occurring, and 2. because of the short time during which an additional plaster-bandage will be necessary. It would be a mistake to fail to provide additional fixation when a marrow-nailing does not obtain a stabile

osteosynthesis, as harmful forces could have an influence on the healing of the bone. Whenever possible we try to obtain a stabile osteosynthesis, not only because of the advantage that we do not need additional bandages so that the adjacent joints can move freely, but especially because only the force pressing the fragments together which is favorable for callus formation can act and not the forces tending to cause lateral dislocation which delay the callus formation. The difference in the callus formation between fractures which were nailed and those which were treated only with plaster bandages, was shown in animal experiments by GRIESSMANN and REICH.

The general principles have not changed in the marrow-nailing of leg fractures. The nailing is performed in the BOEHLER screw-traction apparatus, starting at a small incision placed above the tuberositas tibiae. For the most part a reposition was obtained by the suspension in the apparatus thus making it only necessary to resort to manual assistance in some cases and avoiding the necessity of using traction. 10 - 15 minutes were generally sufficient for the operation.

If the marrow cavity is so narrow at the so-called waist-line (Taille) that the nail cannot pass this place, and if the fracture is located distally from that narrow place, it will also be possible to insert the marrow nail from the inner side of the ankle bone. In this style of operation the marrow nail has only to be driven into the marrow cavity as far as the narrow place. For this reason we have twice inserted the nail from the inner side of the ankle bone, which was accomplished without difficulty. All cases were sufficiently narcotized with Evipan except 2 which were treated with lumbar anaesthesia and 2 with ether-narcosis.

The healing of the wound at the place, where the nail is driven in was in simple fractures per priman except in 2 cases. 1 case, which healed secondarily will be discussed among the complicated cases. The other was transferred to another hospital immediately after the nailing, so no details are available. In cases of simple fractures the time of first weight bearing will usually be determined by the additional injuries. If stability was obtained the patients were advised to start exercising the whole leg the very first day after the operation. When the healing of the wound was complete, no large haematoma nor any additional fractures being present elsewhere, we allowed the patients to be ambulatory. Under the most favorable circumstances the fracture could bear weight after 5 days. Our table shows an average time of 24 days of confinement to bed for all cases of nailed simple fractures of the leg, before the leg is first exposed to weight and strain whereby the cases treated with the spread nail were exposed to weight after 22 days and those treated with the double nail after 26 days. During the period covered by this report we had to transfer almost all the patients to auxiliary hospitals in the vicinity of Kiel a short time after the nailing, and we got to see them very late again because of difficulties of transportation and other circumstances of the war. Thus the statistics show 4 cases with confinement to bed for 81, 48 in 2 cases and 40 days, without any reason being given for this unusual length of time. The statistics under normal circumstances will probably be more favorable. 12 cases of simple fracture were of necessity provided with additional support, 10 of them because of an unstable osteosynthesis, 2 of them because of an additional fracture of the ankle bone.

If a plaster bandage was applied because of an unstable osteosynthesis, it was generally sufficient to bandage the leg for three weeks. We will report separately on cases which had to be provided

with additional plaster bandage for a longer time because of delayed callus formation.

The average time the patient had to remain in the hospital - that is in our clinic and in auxiliary hospitals - was 34 days for simple fractures. But 1 case of most severe arthrosis of both ankle and knee-joints with 120 days, and 2 cases of delayed callus formation and secondary healing with 120 and 150 days, have a very disadvantageous influence on the statistics. Except in these special 3 cases the average time of hospitalization is shortened to 29 days. The average time in our clinic was 10 days for all simple fractures. At the time of the transfer from our clinic to other hospitals most of the patients could have been sent home to be treated ambulantly for the remaining time, but that was not possible because of the frequent air raids and the difficulties resulting from them.

The situation during war-time made it impossible to examine half of the patients after their recovery, thus not allowing us to give exact statistics about the time when the patients were able to work again. Of 22 cases concerning which we received information, 21 cases were reported to have started work again. In 1 case only that of an elderly (60 years) female patient with serious arthrosis deformans, the contrary was learned. These 21 patients, among whom were some with delayed callus formation, were able to resume work again within an average time of 3 months after their discharge from the clinic.

The decrease of the capability of earning average wages was, among the observed cases, between 10 and 30 per cent, and even this only for a period of ½ to 1 year. Only 1 patient with secondary healing and later resection of the fibula, (this case will be discussed here under "nail mishapes") was after 15 months stated to be unable to perform regular work for an additional period of 6 months with a decrease of 40 per cent of earning capacity.

The nail was usually not removed earlier than 3 months after the operation, even when the X-ray showed good callus formation. Only one nail, which was driven in from inside of the ankle bone, had to be removed (after 9 weeks) because of beginning disturbance of joint movement. But this time the fracture showed bony consolidation by clinical and X-ray examination. For the removal of the nail the patients were kept at the clinic for 3 or 4 days or, in many cases, the patient continued ambulatory. Complications occurred in only 3 cases. In 2 patients the nail was inserted so far proximally and was driven into the bone mass quite deep, so that the bone had to be forced open with a chisel. This procedure resulted in an effusion in the knee joint. In the third case the wound healed by secondary intention and 14 days later an abscess developed at the site of the fracture. The fracture itself was completed bony. All 3 patients could be discharged as cured.

The cases of 22 of the 42 patients with simple fractures could be followed up and 18 of them had no further troubles, nor did they show any pathologic symptoms. 1 of the other four cases was the previously mentioned patient with arthrosis deformans. The second case was a 65 year old male patient, whose oblique fracture in the lower third was treated with a double nail and was not stable. In addition he had a fracture of the ankle-bone. Thus he had to be treated for a considerable time in bed with a cast, because of an internal rotation defect. An examination after 1½ year

disclosed pain at the place of fracture, objective swelling of the soft parts and muscle atrophy of 2½ cms, although the fracture showed bony healing.

The different pains of the third patient were not due to the nailing (varices at both sides).

The fourth, a female patient, was treated for oblique fracture of the lower third of the leg by means of the spread-nail with inclined plane. Stabile osteosynthesis could be obtained. At the same time she suffered from a fracture at the ankle-bone which required an additional plaster cast. At the post-operative examination, 5 months after the accident, we found unimportant circulatory disturbances and a healed fracture.

We wish especially to remark that none of the 22 patients examined post-operatively showed any limitation of motion of the concerned joints, and in one case only was there a measurable muscle-atrophy. Except in the two cases mentioned no abnormal edema of soft parts or other disturbances of the circulation were found.

Three cases with a delay of callus formation had occurred, requiring a resection of the fibula. One of these patients had an oblique fracture of the middle of the tibia treated with a double nail, which was not stabile. The other two cases had oblique fractures in the lower third provided with a turn-spread nail and were clinically considered stabile. In spite of that finding a delay of the bone-healing occurred, thus indicating that no absolute stability was obtained and minor disadvantageous forces could work. These facts prove our statement previously made, that oblique fractures in the lower third have to be provided with a rigid spread-system, that is the spread-nail with inclined plane.

A resection of the fibula was undertaken after 8 or 12 weeks, if no callus formation could be detected. Only the fractures treated with a double nail required the use of an ambulatory cast after the resection. All three fractures showed a bony union in no longer than 8 weeks after the resection. The blocking effect of the fibula does not occur in fractures of the tibia alone, which case the fibula causes a blocking effect in every case, but it may occur also, if the fibula was broken too, as was the situation in our three cases, because the fibula healed more quickly than the tibia.

We are sorry to have to record 2 cases of death among the 46 patients. One of these cases was that of a 57 year old man who had, in addition to a simple fracture of the left leg, a compound luxation on fracture of the right ankle-joint, superficial injuries of the skin on both knees, and lacerations of the scalp, as well as a fracture of the left patella. At first the fracture of the tibia was provided with a marrow-nail in the typical manner, and the wounds on the other ankle-joint and the skull were treated primarily. After 8 days, the wound at the place where the nail was inserted being healed primarily, the patella was sewed with wire. After 8 more days an infection arose in the region of the right ankle-joint with the formation of a joint-empyema and a phlegmon of the calf. 3 days after the joint-empyema was opened and the phlegmon was incised the operation-wound of the left leg started to discharge pus associated with an empyema of the knee-joint which also had to be opened. Amputation was considered because of the great suppuration of pus in the area of the luxation-fracture,

but the general condition did not allow the intervention. The patient died 5 weeks after the accident. No relation of the marrow nailing of the leg with the death could be detected because of the severe complicated infections in other parts of the body in addition to the place where the nail was inserted.

The second case was that of a 81 year old patient, who had a fracture of both thigh and leg on the right side with a commotio cerebri. We intended not to perform the marrow-nailing on account of his age and the very weak general condition of the patient, and placed a wire-extension on calcaneus and femur. The patient was very excited and left the bed with splints and extension. We decided to nail after 5 days. 4 days after the nailing the patient died. The autopsy showed: vast confluent broncho-pneumonia of both lungs, thrombosis of the vena femoralis, embolus of a great branch of the right pulmonary artery, lung-infarct with infarct-pneumonia, fibrinous pleuritis, moderate fat-embolism of the lungs, and vast arteriosclerosis of the aorta, the coronary arteries, and vessels of the extremities. The reason for the death of this 81 year old patient was definitely the pneumonia, embolism, and infarct-pneumonia. The medium strong fat-embolism is not an unusual association with 2 fractures of tube-bones. It even must be conceded that every marrow-nailing causes an additional release of fat into the free flowing blood-stream, but this does not do any harm, as has been clinically proven by several hundred cases. See the publications of MAATZ for further consideration of this subject.

Out of the 46 simple fractures 4 comminuted fractures still have to be discussed.

All these four fractures were located in the upper or middle third. Three of the fractures were provided with a double nail, 1 with a nail with inclined plane (Ill. 5).

Table 2 shows that in one case only stability could not be obtained. No disturbances of the wound healing occurred. The fractures were put under weight and strain after an average of 6 weeks. In 2 cases a delay of callus formation was distinctly seen. All these 4 double fractures were provided with a plaster cast for security for the first period of the leg being used. As a matter of routine exercise of the leg was started very early after the operation, when still in bed.

Two double fractures healed with bony union after 6 and 7 weeks (Ill. 6), but in two cases, among them the one that was not stable, the fibula had to be resected on account of delayed callus formation and blocking by the healed fibula. The fracture was cured also in these 2 cases after 4 more weeks. We had the chance to examine 3 of these cases at a later time and detected in only one case a shortening of 1 cm and a limitation of the bending of the knee-joint to 90°. All 3 patients could unrestrictedly perform their regular work, without any decrease of the ability to earn their ordinary wages. The fourth case had to be discussed especially later among "nailing-mishapes".

b) Compound Fractures of the lower leg.

The 64 marrow-nailed fractures of the leg included 15 compound fractures. 12 of them were nailed immediately after admission to our clinic following the care for the complicating injuries; the other 3 at later time.

Table 3.

Compound fractures in the lower leg

15

Site and kind of the fracture

Medium third 7						Lower third 7						Double fractures 1	
transverse fracture 7			oblique fracture -			transverse fracture 3			oblique fracture 4			double fracture 1	
double nail 7	inclined plane -	turn-spread -	double nail -	inclined plane -	turn-spread -	double nail 1	inclined plane 2	turn-spread -	double nail 1	inclined plane 1	turn-spread 2	inclined plane 1	
✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
θ	θ	θ	θ	θ	θ	θ	θ	θ	θ	θ	θ	θ	
61	-	-	-	-	-	1	2	-	1	1	2	1	-

Legend: ✓ stabile
θ not stabile

Table 3 shows again the location and kind of fracture as well as the kind of nail used for the different fractures. The transverse fractures in the middle could be stabilized with a double nail, except for one case; but the fractures in the lower third and the one case of a double-fracture could be put in stabile osteosynthesis in all cases with a spread-nail.

The wounds at the place where the nail was inserted as well as the compounding wounds healed per priman in 7 cases. In 6 cases the wound at the fracture site became infected. In 2 more cases the wound at the place where the nail was inserted was infected too. However, in one case the wounds were so extensive that it was possible only with great difficulty to cover the wound by using incisions to relax the skin around the wound. In the second case the wound was located in an old scar-area which rendered it impossible to treat the wound primarily. All cases could be cured without difficulties by means of opening the wounds and small counter-incisions, thus preventing any bone-inflammation, except in one patient who died and whose case will be reported on at the end of our publication. In only 4 cases was it necessary to currette the fistula which developed after approx. 6 weeks at the fracture site due to small sequestra. The fractures which did not show disturbances of the healing of the wound could be ambulatory after approx. 4 weeks without an additional plaster cast. In all the other cases it was possible for the patient to be ambulatory according to the severity of the infection. But even in these it was necessary in only one case to provide the patient with a plaster cast for walking during 4 weeks. The average time of hospitalization was not longer than for the simple fractures. Only one compound fracture which could not be stabilized with a simple nail, and in which an additional disturbance of the wound healing occurred, had to be

treated in bed for 9 months because of fistula formation and blocking of the fibula. The average time of hospitalization is longer than with simple fractures only in cases with delayed callus formation and severe wound infection.

Because of a delayed healing of the bone fracture in 3 cases, the rapidly healing and blocking fibula required resection. The nail was not removed earlier than 3 months after the operation. As a matter of course the nail had to remain in the bone considerably longer in cases of fractures with delayed healing. It must be pointed out, however, that it will not give as good results to leave the nail alone if the stability is not satisfactory as if the nail is removed and the operation repeated so that a satisfactory stability is achieved. The patients with the ordinary compound fractures (except those with chronic infections and delayed healing of the fracture) were able to start to work again after the same time as patients with simple fractures.

Two of the 15 compound fractures are still under our care, 7 of them were examined later and none of them showed any disturbances of the free motion of the joints adjacent to the fracture.

From the fatal cases the first was that of a 45 year old female patient, who was treated, as recently mentioned, with incisions to remove the tension of a wound 21 cms long. But an infection of the wound occurred anyway. After 3 weeks of feeling rather well without temperature, but with a suppurating wound, the patient died due to a lung-embolism.

The second case was that of a 44 year old patient, who was delivered to the clinic in severe shock with an injury due to a bomb-raid. He was treated at first with a wire extension in the calcaneus. After 14 days the patient had recovered rather well, the temperature varied between 37 and 38°C during the first days, but later decreased to the normal level. The wound of the calf showed some necrotic areas. We regarded the patient as able to stand the marrow-nailing because of his fever-free condition and undertook the operation 14 days after he was delivered to the clinic.

The operation itself was easily completed in a few minutes. Immediately after the nailing a severe collapse of the circulation occurred. 48 hours after the operation the patient died. We are sorry not to have been able to undertake the autopsy due to the conditions of the war. After all we want to remark that the nailing of this patient should have been postponed to a later time without concern about the position of the fracture.

One of the compound double-fractures of the leg was provided with a spread-nail with inclined plane. Though fractures like that in the middle or lower third of the leg are stabilized in the distal fragment by using a spread-nail without harmful effects, fractures of the upper third may show some pushing and transverse forces due to the width of the marrow-cavity of the leg at this place, as the marrow-nail cannot have the same width as the marrow-cavity. In this way the distal fracture healed in this case very quickly, but th proximal fracture showed a delay of the healing of the bone, and for this reason a resection of the fibula was necessary. It is advised, in those double fractures, to drive an additional <u>short</u> nail into the <u>proximal fracture</u>, which nail fills the marrow-cavity, and stability may be obtained that way.

c) Forms of callus.

In his dissertation for the doctor-degree ALSLEV has examined more than 100 cases and all different kind of KUENTSCHER-nailings at our clinic. He found that several kinds of callus-formations may be observed:

1. cloud-callus,
2. trivial callus in the case of ideal reposition and quick healing,
3. favored callus-formation on one side,
4. extensive periosteal reaction.

We understand a cloud-callus to be a plentiful callus-formation but one which appears weak in the X-ray picture, which begins to form after a very short time (Ill. 7). It is extended far more than the callus ordinarily need to be. This kind of callus-formation is found in fractures which have not been nailed only in those cases where several small fragments occur. This kind of callus occurs in nailed fractures even in cases without the presence of a number of fragments, but only in the femur. Also ALSLEV observed the cloud-callus only in fractures of the femur. No cloud-callus was ever detected in X-ray pictures of the nailed fractures of the lower leg.

The second form, the trivial callus-formation with ideal reposition and quick healing, is found, for the most part, in nailed fractures of the lower leg (Ill. 8). Checking 43 nailed fractures of the lower leg we found this kind of callus formation 35 times. Only 43 X-ray pictures could be investigated in this regard as all the other pictures have been lost on account of war events.

The very trivial callus formation is observed in all patients with quick bony healing of the fracture, when a real ideal location of the fragments and a stabile osteosynthesis was obtained by the marrow-nailing. 39 of the 43 X-ray control pictures showed an anatomically ideal position. 35 of these 39 patients showed trivial callus formations, but 4 patients showed a periosteal reaction extending far beyond the fracture, two of these 4 patients having been provided with a double nail, and 2 with a spread-nail (Ill. 9).

This widely extended periosteal reaction was supposed by KUENTSCHER to be caused by the mechanical and also chemical irritation of the marrow-nail (Callus without Fracture, KUENTSCHER). We believe today, that this reaction occurs only in youth, as MAATZ has also reported at the German Congress of Surgeons in 1944. This fact is possibly related to the circumstance that the elastic periosteal layer is lifted from the bone for a wide extent by the fracture-mechanism. The cases mentioned by ALSLEV are those of youths in the age group of 7 to 20 years. Also our 4 cases were of patients in their youth, namely 17th, 17th, 19th, and 20th year.

The favored callus formation at one place is observed in fractures, of which the fragments did not have axial position (Ill.10).

We know that callus formation depends to a rather great extent on mechanical rules, and there is no doubt that forces pressing the fragments together act favorably to callus formation, but continuous distraction retards it. Thus, we find in an angulated fracture a stronger formation of callus on the concave side, viz. the place of greatest pressure, in comparison with a weak callus formation on the convex side. After the healing of the fracture two patients had a valgus-position and one patient a recurvation of the lower leg.

In these three patients an increased callus formation was observed on the concave side.

d) Pseudarthroses.

The first of the two cases of pseudarthrosis of the lower leg treated by nail was that of a 20 year old man with amputation of the left femur and pseudarthrosis in the lower third of the right lower leg (Ill. 11). The distal fragment was completely dislocated to the rear and a filthy wound the size of the palm of the hand lay over the proximal fragment. The injury occurred 1½ years before. After the excision of the ulcer both ends of the fracture were freshened (the surface cut or curretted away to form the same conditions as after a fresh fracture), and the fracture was then provided with an especially strong spread-nail with inclined plane on account of the width of the marrow cavity (Ill. 12).

Ordinarily we prefer the oblique freshening (GUENTZ) so as to create larger planes of contact. In that case the pseudarthrosis was located too close to the joint, and we had to perform a transverse freshening as otherwise it would not have been possible to use a marrow-nail. As might be expected an infection occurred, some bone splinters separated and the suppuration of pus caused a loose fit of the nail. Thus it was necessary to apply an additional plaster cast. The patient is still under our care, but he is already able to walk without the plaster cast with an orthopedic shoe and orthopedic splints. After the complete fixation of the fracture no additional splinting will be necessary. The advantage of the marrow-nailing in that case was the prevention of greater dislocations during the healing period and it was possible to use the leg earlier than it would have been when treated some other way.

The second case is that of a 25 year old girl with a pseudarthrosis in the lower third. In this case we could perform the oblique freshening, the fracture was fixed with a double nail, stabil osteosynthesis was obtained, and no additional fixation was necessary (Ill. 13). The wound was not closed after the operation and we left it to heal per granulationem. After 6 weeks the wound had closed sufficiently so that the patient was able to use the leg and to walk without a cane after a short time.

e) Late nailing in the presence of purulent infections.

We will report on the only case of late nailing in the presence of infection at the end of our article.

f) Complications of the nailing.

One patient had a transverse fracture in the lower third of the tibia and was supposed to be treated with a turnspread nail; but the elastic round part of the nail bent, when turned around for 180° as necessary, like a serpentine (see in the technic; KUENTSCHER and MAATZ), so that its effect as a spread nail was not obtained. Therefore the turn-spread nail was replaced by a double nail.

In a second case a normal strong turn-spread nail was to be inserted. It occurred that, at a relatively narrow point but not too narrow marrow-cavity, when the second nail was driven in, both nails blocked in such a way that the nails could not be driven in any further nor pulled out again, thus the second nail, which should have been driven in 4 cms farther had to be broken off by force. When it was attempted to drive the nails in with force the fracture

happened to bend and the surfaces did not come together (Ill. 14). After 2 months both nails were removed with great difficulty and replaced by a simple thin nail, as no callus had formed because of the distraction.

In a third case, with a refracture occurring 3 weeks after the marrow nail was removed, due to another accident, a too strong nail was choosen by mistake, which could neither be driven past the site of fracture nor pulled out again. Also this nail had to be cut off at the entry of the nail. Both these cases show distinctly, that the directions of KUENTSCHER and MAATZ must be considered carefully, and in case of doubt, a smaller nail should be preferred to an attempt to drive in the nail by force if it is blocked. Furthermore, care must be taken that, if ever the nail starts to block, it has to be drawn out again in time. If the nail can not be driven in by ordinary hammer-strokes for a distance of approx. 2 cms at every stroke, and if a changed sound occurs, it is advised to pull the nail out at once. It must always be cautioned to never drive the nail in with great force under any circumstances. If the nail has blocked after being driven in by great force, it takes hours of troublesome difficult work to get the nail out again, by any means (block-and-pulley etc.). Those attempts are needless and in addition the operation is lengthened considerably. Therefore the correct nail has to be carefully chosen, so that the nail goes in smoothly and with the correct sound, to prevent such situations. If blocking ever occurs, it is advised to cut or saw the nail off and to terminate the operation as soon as possible.

g) Recapitulation.

This view of simple and compound fractures of the lower leg shows, that the shape of the nail has to match the kind of fracture, to obtain a stabile osteosynthesis. For this reason the double nails which were generally used in the beginning are only to be used in some single exceptional cases. The use of the different spread-nails is recommended. Only if a stabile osteosynthesis is obtained, is no additional fixation necessary. An ideal reposition was obtained in most of the treated fractures; the results are anatomically and functionally excellent. Almost always within 3 months after release from the hospital the patients were able to work again. It was only in some few cases necessary to give a pension to the patient for a limited time. No pseudarthrosis has been observed. In some cases the blocking fibula had to be resected due to delayed healing of the fracture. The average time of hospitalization was 34 days. The nailing of fractures of the lower leg has considerable advantage over other methods of treatment, most of all the possibility to move the joints and train the muscles very early. Only by this method of treatment is it possible to use the leg early, the healing usually progresses quickly, without muscle-atrophy or stiffening the joints. The sources of danger and cases of death at the nailing will be discussed later. The operation is, with some exceptions, very easily and quickly performed, in a few minutes.

2. MARROW-NAILING OF THE FEMUR.

During the period of this report, 49 fractures of the femur were nailed, 35 of them were simple fractures, 7 compound fractures, 4 metastases or bone-tumors, 2 osteotomies, and 1 late nailing in the presence of infection. Patients of both sexes and of the ages group of 4 to 70 years were nailed. Every fracture of the femur was nailed, except if the nailing was not recommended because of the kind of fracture (close to the joint or reaching in the joint) or to other

additional complicating injuries or diseases, in cases of adults. In cases of children we only decided to nail if no other method of treatment (SCHEEDE's vertical suspension, extension, or plaster-cast treatment) could bring about a satisfactory fixation (Ill.15,16,17).

As a satisfactory reposition can generally be obtained without great difficulty in juvenile fractures, minor faults of fixation regulate themselves later on, and no restriction of movement of the joints has been observed. Thus the many advantages of the marrow-nailing method can be considered not so important in the case of children. If an infection occurs in a compound fracture this will stay restricted to the place of the fracture in the case of adults, but in the children a true osteomyelitis may develop. This is one more reason to be cautious about the nailing of femur fractures of children.

Whenever possible the nailing was performed immediately after the delivery of the patient into the hospital. The immediate nailing was not undertaken if it was a case of a shock, or one of extensive injuries of soft parts (because of the threat of fat-embolism). If the nailing could not be performed immediately, for one or the other reason, a wire extension was applied to prevent any shortening of muscles and thus making difficulties at a later repositioning.

The technic formerly used at our clinic is still performed. We regard it necessary to point again to the fact, that the choice of the nail has to be made very carefully, and that in case of doubt it is better to take the thinner nail than the thicker one. The choice of the correct thickness of the nail is not possible if only a partial X-ray picture of the femur was made! To determine the width of the marrow-cavity X-rays of the <u>entire femur</u> have to be made from <u>two</u> planes. As the repositioning may cause considerable difficulty in persons with strong muscles, far more than with the other long bones, a suitable repositioning device has to be available as well as the facilities to apply traction in every direction. The use of traction or of a repositioning device may, as it occurred to us, do considerable harm to the surrounding soft parts. Thus we observed earlier in a juvenile patient with a fracture of the femur a twisting off of the elastic periosteal coat for almost the entire extent of the femur. A good possibility for directing the proximal piece can be obtained if a marrow-nail is <u>inserted in it before the reposition is performed</u>. By this procedure we have not needed any repositioning device recently.

For more details we refer to the book of KUENTSCHER and MAATZ.

<u>a) Simple fractures of the femur</u>.

Of the 35 cases of simple fractures, 2 were patients with fractures on both sides, 32 fractures were in the middle and upper third, 3 in the lower third. A stabile osteosynthesis was obtained in 27 cases. Two of the fractures, which were not stabile, were located in the lower third, where no stability was expected anyhow on account of the width of the marrow-cavity at this place. Three more cases were not expected to be stabilized on account of extensive comminuted fractures or large pieces of the corticalis having been broken out. In three of the unstable cases the leg was only placed on a BRAUN splint for some time. In three other cases, which might have shortened in spite of the nail, it was necessary to attach an additional wire-extension (Ill. 18, 19). In one case no stability was obtained on account of the choice of a nail which was too thin, thus enabling the distal fragment to rotate.

Disturbances of healing at the place where the nail was inserted occurred in only 2 cases: 1st in the patient with the fracture on both sides; the infection was minor; 2nd, another patient with extensive infection and finally exitus. This case will especially be reported on.

The marrow-nailing operations in children were made under ether narcosis. 2/3 of the adults received Evipan narcosis and the rest lumbar anaesthesia.

In 2 cases fractures of the femur of children, which were not suitable for nailing at first on account of a fragment sticking in the fracture cleft, had to be nailed and the reposition performed after the fracture was laid open. The healing of wound and bone was completed without complications. The fractures of these children required nailing, as they could not be corrected by extension-treatment.

Patients with stabile osteosynthesis and without infection may use their leg on an average in 24 days after the operation; the shortest case was 7 days, the longest 42 days. If no stability was obtained it took 8-12 weeks (average 70 days). The only patient with infection was able to use the leg 84 days after the operation (Table 4).

Table 4.

	Average first use and weight bearing in days:			Average time in hospital	
	stabile fractures	not stabile fractures	infections	stabile fractures	not stabile fractures a. infections
ractures in e femur imple and mpound)	24	70	84	40	120

We were only able to follow up the cases of those persons who did not work at all or youths, therefore we can not give any facts as to when the patients were able to start work again. But all the examined persons were free of any disturbances after an average time of 3½ months. No limitation of the movement of the joints or muscle atrophy was found of a degree worth mentioning, after the discharge from treatment.

These findings are nearly the same as those given by KOIKY in his thesis completed at our clinic (Report on the first 89 simple fractures at the femur) (Ill. 20, 21).

As can be seen in table 4 the average time of hospitalization was 40 days in cases of simple fractures of the femur which were stabilized. The average time for the fractures which were not stabilized, including the only case with infection, was 120 days.

The nails were removed in the early cases 4 months after the operation. Some patients did not have the nail removed after more than a year, one patient even after more than 2 years, without any harm. SCHUETTEMEYER will report on examinations of the blood

picture of nailed patients. For the most part the patients returned to the clinic for 4 or 6 days to get the nail removed. If there were favorable conditions at the patients home it was possible to remove the nail and allow the patient to go home.

We are sorry to have to report one fatal case in several hundred with the nail removed. It was the case of a patient with fractures of both femurs, which had healed well both functionally and anatomically. When the nails were to be removed after more than a year a very difficult situation occurred on one side because of the very deep insertion of the nail. The trochanter major had to be opened with a chisel to facilitate the extraction. An infection of the wound occurred with an empyema of the hip-joint, which had to be opened, and a phlegmon of the thigh developed, followed by a sepsis, which was the cause of the patient's death.

b) Fatal cases.

A 25 year old patient, delivered at the clinic with a commotio cerebri, fractures of the femur and the radius, was nailed under Evipan narcosis 4 days after he came to the hospital. The operation was completed without complications. Failure of circulation occurred and the patient died 2 days post-operative.

Another patient with commotio cerebri, fractures of the femur and vertebrae, was nailed 8 days after his admission to the hospital. Also this operation was completed without complications. This patient too died a few days after the operation owing to failure of circulation.

These cases indicate that a patient with a commotio must not be nailed, even if the commotio is subjectively and objectively not causing any trouble at the time of operation, or even if the commotio, as in our two cases, was only of slight degree.

In a third patient it was the case of a compound fracture of the head of the tibia in addition to a fracture of the femur of the other leg. An empyema occurred at the knee-joint of the leg which was not nailed, and a general sepsis developed. This patient died after 3 weeks. Death in this case certainly was not caused by the nailing.

The nailing of the simple fracture of the femur of a 54 year old patient was undertaken. The operation itself did not lead to any complications. The fracture was located in the lower third and a stabile osteosynthesis was not obtained. Therefore the thigh had to be placed on a BRAUN splint. Because of air raid defense the patient had to be transferred to an auxiliary hospital, 80 kms distant, one day after the operation. 10 days later an erysipelas occurred at the place where the nail was inserted, the secondarily healing wound was opened wide. It was not possible to bring the patient back to our clinic until one month after that event, when abscesses of the thigh were opened immediately. The patient died few days after this. We are certain that in this case death would not have occurred, if it had been possible to control the patient daily at our clinic.

c) Compound fractures of the femur.

7 compound fractures of the femur were nailed, 4 of the patients did not show any difference in the process of healing, period of hospitalization, and time of the first use of the leg, in comparison with the figures for the simple fractures. The wounds healed per

priman. One patient was nailed immediately after he was delivered at the clinic, 3 patients had to wait until the wound had healed.

In 3 of the 7 patients a stabile osteosynthesis was obtained. One patient with a gun-shot fracture of the femur, could not be stabilized. He was provided with an additional wire extension and the fracture healed with 3 cms shortening (Ill. 20, 21).

The 5th patient, with the fracture in the lower third of the femur, had a complicating wound close above the patella. As no stability was obtained on account of the location of the fracture, a plaster cast of the pelvis was applied for 3 weeks, during which time the wound healed. In the area of the wound, which healed primarily, considerable cicatrization of soft parts occurred with severe limitation of motion of the knee-joint.

The 6th and 7th patients were children of 5 and 6 years of age. After the nailing, undertaken primarily during the wound treatment, an infection of the wounds occurred. In both cases after 3 months of suppuration of pus, a typical ring-sequestrum formed, as has been described by FISCHER and REICH. Both cases showed marked periosteal callus formation. The nails were removed after 4 months. The fracture was consolidated in both cases after the sequestrum was removed.

No limitation of the action of the joints or muscle-atrophy was detected in either child after the removal of nail and sequestrum.

d) Nailings of metastases and spontaneous fractures.

A brown tumor was detected in a 10 year old boy 1 year previously, located in the area of the trochanter minor of the femur. The boy suffered a fracture at that same place caused by a slight trauma. No satisfactory position could be obtained by wire-extension and bed rest. Therefore the marrow-nailing was performed without exposing the fracture (Ill. 22, 23). After 14 days a strong formation of callus was observed, and the nail could be removed 4 months later.

In 2 older persons the nailing of the femur was performed prophylactically because of metastases at the upper third of the femur, following an amputation of the breast because of carcinomas (Ill. 24). In addition to this the patients were treated with irradiation, as we had seen in two earlier cases that the patients reacted well to this treatment, with freedom from pain; they could also walk again, and the metastases were no more to be seen in the X-ray picture.

Another very interesting case is that of a 32 year old colleague, who had a fascia-sarcoma removed from his femur 12 years before. After the operation an intensive X-ray irradiation was started, though it had been thought advisable to disarticulate the femur on account of the histological picture. X-ray damage occurred to the skin, which made skin grafts necessary. The colleague then did not feel any disturbances until October 1945. He continued engaging in sports and was at the front during the war until the Fall of 1945. In November 1945 a spontaneous fracture suddenly occurred at the femur, without any X-ray evidence of a metastasis. The muscles on the outside of the thigh were atrophic to a high degree. A broad rough area of scars was found at that place, the other muscles were in good condition. It cannot be ascertained

quite clearly which factors caused the spontaneous fracture. It might have been a case of fatigue fracture (Ermuedungsbruch) due to the effect of muscle pressure, or just as well a belated damage due to radiation, a kind of osteo-radionecrosis, or, the spontaneous fracture may have been caused by a combination of both these factors. The fracture was treated in a hospital outside the town with a wire-extension traction cast for 3½ months. Then the patient was allowed to walk with a cane. When the patient first asked our advise, we found a bent femur, of the form of a varus, due to the effect of muscle pressure from one side with good callus formation on the concave side and absolutely no callus formation on the convex side. The fracture was elastic and we advised the patient to consent to a marrow-nailing. This was performed without exposure of the leg at the site of the fracture (Ill. 25, 26, 27). After 10 days the patient was able to stand on this leg for the first time without suffering any pain. After 4 weeks he was able to walk for 2 hours, supported by a cane. After 5 weeks distinct signs of a callus formation were detected at the outside of the femur fracture. After 7 weeks the patient started work again (Ill. 28).

e) Osteotomy.

In a 22 year old patient a femur fracture was treated with wire-loops in another hospital. A shrinking of the leg of 5½ cms occurred, with angulation of the axis in the form of a varus (Ill.29). An osteotomy and marrow-nailing was performed (Ill. 30). The wound healed without complication. The previous shortening could be overcome except for a difference of 1½ cms.

In a 63 year old patient with a double fracture of the femur healed with considerable bending of the axis and shortening, an ideal position was obtained with a correcting osteotomy. Unfortunately, however, the patient died, owing to post-operative shock.

The treatment of both the patients was primarily carried out in an hospital outside the town.

f) Late nailing in the presence of infection.

This case, nailed when already suppurating, will be discussed at the end of this report.

g) Forms of callus.

The different kinds of callus formation have already been discussed by us when dealing with the fractures of the lower leg. Vast periosteal reactions are nearly always observed in any case of a fracture of a juvenile femur (Ill. 31). The trivial formation of callus and the kind which we called "cloud callus" are found just as frequently in femur fractures.

h) Recapitulation.

The procedure of the marrow nailing of the femur usually does not cause any difficulties. It is advised that the marrow-nail should be inserted into the proximal fragment before the repositioning is made, thus avoiding the use of traction or repositioning apparatus, as it is possible in this way to direct the fragment and to reposition it easily. In almost all cases a stabile osteo-synthesis will be achieved, which has the advantage that the joints

can be freely moved early and the muscles trained. For this reason we usually do not find any limitation of the motion of the joints or a muscle atrophy. Therefore the time of treatment is much shorter than with other methods of treatment. The average of the time that the marrow-nailing method saves in respect to other methods is 50 per cent less than the time-indexes given by BOEHLER for other methods of treatment.

Even in cases of fractures which are not completely stabilized and required an additional wire-extension, the marrow-nailing method has the advantage that no severe dislocation of the fragments can occur, as occurs frequently, because of the traction of the gastrocnemii in the lower third of the femur.

A juvenile femur is nailed in case all other methods fail to stabilize the fracture. Extensive bruises of soft parts, commotio cerebri, or shock forbid the nailing under any circumstance.

Compound fractures require care for the wound and immediate nailing. Poorly positioned fractures can be corrected even after they are healed without very much danger of shortening the leg by performing corrective osteotomy and final nailing. The removal of the nail should not be made before the X-ray picture definitively shows an absolute bony healing of the fracture. It has proven not to be harmful when the nail rests in its place for as long as two years.

When bone metastases are proven in the femur a prophylactic marrow-nailing is proposed.

3. MARROW-NAILING OF THE HUMERUS.

a) Simple fractures in the humerus.

The 14 operated fractures in the humerus included 10 simple fractures, 2 pseudarthroses, 1 nailing because of bone metastasis, and one case concerned a compound fracture which was nailed after several months in a purulent state. The latter will be discussed together with similar fractures of the other long bones at the end of this article.

The age of our patients was from 19 to 86 years. All the cases were treated under Evipan narcosis except the 86 year old patient who received local anaesthesia.

7 of the patients were nailed immediately after admission to the hospital, 3 other patients after 2, 9 and 14 days respectively. The simple or double nail, adapted to the width of the marrow-cavity and the length of the humerus, was used.

According to the site of the fracture in 7 cases the nail was inserted from above and in 3 cases from the fossa olecrani, following the directions of KUENTSCHER and MAATZ. The technique has not changed recently, but we regard it as necessary to point out the fact, that the hole in the corticalis where the nail is inserted, must be larger than usual and inclined, as otherwise the insertion of the nail would be rendered difficult and a bursting of bone around the hole could occur.

No stabile osteosynthesis was obtained in one fracture with a triangular separated piece of bone at the site of the fracture. All the other nailings were stabile after the nailing. The healing

of the wounds was in all cases per primam. No additional bandages were necessary.

The average time of hospitalization was 11 days. No fatalities occurred. No special complications occurred. All fractures healed by bony union. The follow-up examination showed a restriction of rotation of 1/3 in the 87 year old patient, but that did not keep him from splitting firewood every day. No muscle-atrophy or limitation of movability was found in the other patients.

We observed in nearly all cases of fracture in the humerus a slight callus formation. Only infrequently was a considerable callus formation found.

In all cases the nail was removed when the X-ray examination showed bony healing.

b) Pseudarthroses.

A pseudarthrosis due to gun-shot injury was treated after the site of fracture had been laid open and the surfaces of the pseudarthrosis freshened on an oblique plane. The bone-splinters which were chiseled off, were fixed at the proper location with wire loops. A stabile osteosynthesis was obtained. The wound healed per primam. An additional abduction cast was split in the shape of a basin after 11 days and could be removed after 4 weeks. The pseudarthrosis healed by bony union.

The second patient was nailed in another hospital in January 1945 because of a fracture of the humerus. The patient worked very hard and soon afterwards the wound had healed. In September 1945 he felt an abnormal irritation in the middle of his arm above the elbow. X-ray investigation showed a pseudarthrosis with a wide cleft. The marrow-nail had broken at the site of the fracture (Ill. 32).

The pseudarthrosis was laid open, the broken marrow-nail was removed and replaced by a stronger nail, after the pseudarthrosis planes had been freshened transversely. Moreover a bone graft from a rib was also placed in a slot chiseled into the bone (Ill. 33). The wound healed per primam. The arm was placed at rest for a short time after the operation with a splint. The patient remained under ambulatory treatment after he had been discharged from hospital a fortnight after the operation. The graft healed in the consolidating fracture. No limitations of motion were found in the arm.

c) Metastases.

In a 71 year old colleague we found 2 large metastases in the left arm above the elbow with bronchial carcinoma, causing a spontaneous fracture (Ill. 34). The marrow-nailing was performed. The patient was able to begin motion a short time after the operation without additional bandages and without pains. Nothing further can be said about the process of the healing, as the patient did not show up for follow-up examinations.

d) Recapitulation.

The marrow-nailing of the humerus has an advantage over other methods of treatment in that no additional abduction or extension bandages are required. The joints can be used immediately after the operation and thus no limitation of motion results. The time required for treating the patient in hospital is very short.

4. MARROW-NAILING OF THE FOREARMS.

Altogether 28 nailings were performed at the forearm; 16 of them were simple fractures, 2 compound fractures, and 10 pseudarthroses. Patients of both sexes were of the age from 16 to 62 years. The simple fractures were nailed primarily except 3. In 2 cases we could not nail immediately because of shock. The third patient was provided with a plaster-cast at first and then discharged, as he had been injured in a bomb-raid and on account of this attack we had been kept busy with a great number of patients. As the fracture showed a poor position we nailed it after 3 weeks.

All dislocated forearm fractures were usually nailed. Of course no fractures could be nailed which were located too close to the joint. The technique has not changed recently. We refer to the report of MAATZ during the Congress of Surgeons in 1943. Especially important is the correct choice of the length and thickness of the nails, for if no stabile osteosynthesis is obtained distraction and lateral dislocation forces are easily produced at the fracture site, and these lead to pseudarthrosis.

a) Simple fractures of the forearm.

Among the 16 fractures in the forearm were 10 cases with both bones broken, 4 of the cases showed only the ulna and 2 only the radius broken. More frequently than in the other long bones the reposition causes difficulty because of the narrow marrow-cavities. In 6 of the 16 cases the fracture had to be exposed, among them were the cases nailed late after the accident and which had to be exposed anyhow.

The wounds healed per primam except in one case. The operation was completed in Evipan narcosis except in one case in which plexus anaesthesia was used.

In only 2 cases of the simple fractures stability could not be obtained, and therefore a plaster cast was applied for 2 and 3 weeks.

The period of hospitalization averaged a fortnight in all cases of simple fractures. In patients whose fracture was not exposed the average time was 5 days.

Bony healing occurred in all cases except one. In this patient a fracture of the ulna was nailed primarily with the nail placed ideally (Ill. 35). After 4 weeks the patient started again with his heavy work as a locksmith. 2½ months later the patient felt pain again and asked us for advice. We found the nail broken at the site of the fracture and a distinctly visible cleft in the ulna (Ill.36).

The broken nail was removed, the pseudarthrosis freshened, the fracture nailed again, and a graft from the tibia inserted in addition.

The mistake had been made in this 21 year old patient to allow him to start too early with his heavy work. The fracture showed no complete bony healing, and, even though the nail was chosen as carefully as possible, there were sufficient forces acting to shift the fracture, because of the continuous use of the arm. This process led to changes in the forming bone-tissue and finally to pseudarthrosis and breaking of the nail.

Even though the forces shifting the fracture are not very great, as this case demonstrates, they can cause considerable complications. Sometimes, as we can observe in cases where too short a nail was chosen for the radius or ulna and thus in sufficient friction was obtained, the nail wanders out of the bone. Especially in cases of ulna fractures near the elbow the nail is likely to be forced out. Therefore MAATZ proposed that conical nail should be used for this type of fracture. Even though it occurred in two patients that the nail wandered out of the bone, a bony healing was obtained after the nails had been driven in again.

In one case an extensive bridge callus formed with a good healing of both the forearm bones, thus completely preventing a rotation. The bridge callus was removed operatively and a fat-lobe inserted. Rotation was obtained again although it was limited in amount.

In a 60 year old woman the nailing could not be performed until 10 days following the accident, as she was admitted to the hospital in shock caused by bomb injuries and with numerous wounds in the head. The wound healed at first per primam, after an abscess in her face had drained; but one month later an abscess developed in the place where the nail was inserted into the ulna, followed by disturbances of the blood circulation in the soft parts and a SUDECK dystrophy in the forearm bone. A limitation of the motion of the wrist joint was left after the fracture had healed by bony union.

In the other patients no muscle atrophy occurred after the bony healing nor a limitation of motion in the joints. The shortest time of removal of the nail was 7 weeks after the operation, but usually not before 3 months.

The callus formation is usually very slight. The cleft at the fracture site is frequently visible for a long time, though the fractures are stable after the removal of the nail.

Many patients resumed their light work again after the wound of the stitch-incision healed (7 days), but it is not advisable, for the reasons mentioned before, to let the patient start with any kind of heavy work before the 12th week.

No pensions were paid. Even the 60 year old woman, whose fracture had healed with limitation of the motion of the wrist-joint, did not receive a permanent pension.

b) Compound fractures in the forearm.

In the first a defect fracture occurred in the ulna with a complicating soft-part injury of the size of the palm. The nailing was performed immediately and the wound left to heal secondarily (Ill. 37, 38).

The wound healed comparatively soon. The patient was in the clinic only 2 days and was then treated ambulantly. It was most astonishing that the 4 cms defect was bridged over with a bony bar (Ill. 39).

The patient resumed his work. Changes in the area of the bony bar occurred, even though the nail was left in its place. A pseudarthrosis developed (Ill. 40, 41).

In the second patient, 16 years of age, an open fracture in the left forearm had occurred, and in addition to this a fracture in the head of the left arm above the elbow and a number of skin wounds in the area of the entire arm and the face. Because of the wounds it was at first decided not to nail. But the fracture in the forearm could not be stabilized. Therefore we decided to nail at least one bone and chose the ulna. A chronic suppuration occurred which pushed out several sequestra. We were not able to follow up the case of this patient as he was an alien.

c) Pseudarthroses.

The pseudathroses included 6 isolated ulna pseudarthroses, 3 isolated radius pseudarthroses, and one pseudarthrosis in both the forearm bones. The pseudarthrosis in both forearm bones was transversely freshened, provided with a marrow-nail in both bones, and it healed by bony union without complications. The follow-up examination after six months showed absolute free motion of the stabile forearm.

Very unsatisfactory prospects for healing are to be expected in the isolated pseudarthroses of radius or ulna, as in either of the cases the corresponding sound bone causes blocking and no pressing forces are able to act. In only 3 cases of split-pseudarthrosis was it sufficient to nail and split the bone according to the method proposed by KIRCHNER. In one of these 3 cases the healing progressed very slowly. We had to perform an additional BECK drilling after some months. Then this pseudarthrosis also healed by bony union.

In one case of a defect-pseudarthrosis in the ulna no healing could be obtained after the nailing was performed only after splitting open the bone and without bone graft. In the other pseudarthroses of ulna or radius an additional chip of tibia or rib was transplanted when it was nailed. If possible a chip of a rib should be used to prevent the patient from lying in hospital too long and to permit his being ambulatory early.

In one isolated defect-pseudathrosis of the radius a freshly resected piece of fibula was placed between the freshened ends of the fragments and kept in place while "strung" on the marrow-nail (Ill.42.

When the corresponding bone was in a wrong position an osteotomy was performed on that one too (Ill. 43, 44).

In all these patients bony healing could be obtained. We could, however, not follow up these cases of 2 of the patients as it was not possible to get hold of them any more.

The operation lasted on an average 2 hours, if an additional graft was transplanted, and was nearly always performed in Avertine-ether narcosis. Although the ordinary marrow-nailing does not cause any great difficulties to a skilled person, the rather difficult marrow-nailing of forearm pseudarthroses requires a considerable technical knowledge, and this operation should only be performed by surgeons who have the necessary experience in the field of marrow-nailing and bone-surgery.

In three cases the wound healed secondarily, but this did not delay the healing of the bone fracture. The suppuration in these cases lasted only a short time. In the other case the suppuration lasted several weeks and no bony healing could be obtained (this case has already been mentioned above).

In all these cases an additional plaster-cast was applied, although stability was obtained, and the cast remained until the healing of the wound was completed.

The patients with primarily healed wounds remained in the hospital for an average time of 1-2 weeks, but the 2 patients with secondarily healing wounds had to remain 4 and 5 weeks respectively in hospital treatment.

4 cases, which could be followed up, showed anatomical and functional first-class results with the joints moving free.

d) Recapitulation.

The marrow-nailing in the forearm is the most difficult of all marrow-nailings, as can be seen by the high percentage of cases which required that the fracture should be exposed, by which a great advantage of the marrow-nailing method is given up. No disturbances of wound healing were observed in simple fractures. In all cases an excellent anatomical and functional result was obtained. Usually no additional bandages are required for closed fractures. The marrow-nailing allows one to obtain an ideal fixation in the treatment of defect-pseudarthroses, as renewed dislocation cannot occur. For bridging over isolated ulna or radius pseudarthroses it is usually necessary to attach a bone graft, as the sound second bone has a blocking effect and prevents the healing.

5. LATE NAILING IN PURULENT FRACTURES.

In January 1944 a 44 year old patient suffered a compound fracture in the left lower leg during an air-raid. A chronic fistula in the area of the fracture occurred and no bony healing was obtained even after 4 months. The fracture did not show a satisfactory position. The intact fibula acted had a blocking effect. Therefore after 4 months we decided to nail the fracture, after resection of the fibula and freshening of the surfaces of the fracture, though the fracture was suppurating and high temperature occurred frequently (Ill. 45). An additional plaster-cast was applied. Nine months after the nailing, when the fracture was bridged over with bone, the nail was removed (Ill. 46).

The patient was able to walk 8 weeks after the nailing, provided with an ambulatory cast which was left for 2 months. Then the patient walked without the cast, but the fistula did not decrease until the nail had been removed. The patient did not feel any discomfort and walked with a cane. After the nail had been removed the patient had to be admitted to the clinic again, to remove small sequestra. He then was discharged as healed. In the beginning he received a pension of 30 per cent.

Thus, the situation did not lead, as one might have expected, to a general suppuration of the bone-marrow, but the formerly heavy fistulization from the fracture site decreased very considerably when the latter had been stabilized by the marrow-nail. Not having healed before for 4 months, the fracture, after being nailed, healed by bony union within 3 months.

The inserted nail acts in those cases as a drain-pipe. As a matter of course neither the place where the nail was inserted nor the wound must be closed. The temperature steadily decreased until it became normal after the nailing, as also in the following two cases. The second patient had a gun-shot fracture in the right

femur in August, 1945 (Ill. 47).

A comminuted fracture was found with a wound the size of the palm. The patient was brought to our hospital from a clinic in another place with a wire extension. A very strong suppuration set in. The wound which had been the size of a hand grew smaller very slowly. The patient constantly had high temperature, up to 39° and 40° C. No satisfactory position of the fragments was obtained. Several X-ray examinations showed progressing angulation. Therefore it was decided to nail, after almost 4 months, even though discharging freely. The fragments were exposed, great sequestrated bone pieces were removed and the fracture fixed with a marrow-nail (Ill. 48). An ideal reposition was obtained after the nailing.

The wounds were left wide open. The severe suppuration subsided very quickly and the temperature decreased thus making the patient feel well again for the first time. After 5 months the fracture showed complete bony union.

7 weeks after the nailing the patient started to walk about. About eighteen months after the nailing the nail and some small sequestra were removed from the small fistula. The contrast-medium outline of the fistula after the removal of the nail was seen to extend along the previous marrow-nail canal, which we know to be separated from the marrow-cavity by connective tissue.

The discharge of pus was inconsiderable.

The patient was able to walk very satisfactorily in a relatively short time, feeling really well for the first time, and was discharged without untoward results. A shortening of 2 cms and a limitation of the motion in the knee-joint (bending only up to 100°) remained.

On account of the critical general condition, the large complicating soft-part injuries and the marked suppuration, we considered amputating the leg several times before the nailing. We were able not only to save the leg of the patient by the marrow-nailing, but could also at once influence the general condition for the better.

In a third patient we found a compound fracture of the humerus, multiple rib-fractures, fractures of the scapula, and a paralysis of the ulna. The very extensive and dirty wound of the arm above the elbow could not be cleaned thoroughly. A primary nailing was not performed on account of the great number of persons injured at the same time. The arm was at first only placed on a KRAMER splint and provided with a wire-extension. Later on, as the temperature increased, an abduction-cast was applied to keep the limb at rest. The fracture was in poor condition. Therefore it was decided to nail after 4 weeks in spite of the suppuration (Ill. 50). A chronic infection occurred and sequestra formed in the area of the fracture. After the removal of the sequestra a bony consolidation was obtained finally in an anatomically ideal position of the fragments (Ill.51).

In this case also amputation was considered. Even though we do not have great experience in the late nailing of purulent fractures we venture to say that the suppuration subsides when a really ideal resting position is obtained. The general condition usually improves immediately. Also the experiences of KUENTSCHER collected during the war in a large number of patients prove this assumption (Congress of Surgeons 1944).

6. GENERAL RECAPITULATION.

The marrow-nailing of 155 fractures is reported. The tables show the distribution of the cases among the different long bones and the kind of fracture. In general we maintain our formerly reported experiences that the marrow-nailing method has considerable advantages over other methods of treatment, above all in the possibility to use the joints again very soon, and thus train the muscles before they atrophy. Therefore the patient may considered to be really healed and able to work after the fracture is healed by bony union, and no lengthy physiotherapy follow-up treatment is necessary.

The aim of every marrow-nailing is the stabile osteosynthesis. This can be obtained, as the examinations of the fractures in the lower leg have proved clearly, only with the utilization of spread-nails.

If only the simple nail is used for nailing the lower leg the results will be decidedly worse. This explains the fact that some surgeons decline to perform the nailing in the lower leg.

The technically most difficult nailing is the nailing of the forearm. This should therefore be left exclusively to surgeons familiar with the marrow-nailing.

The period of hospitalization and the time by which the patient was able to work again was much shorter than the time stated in care of all other kinds of treatment.

The hazards of marrow-nailing and how to avoid them has been pointed out in the various sections of this paper.

Illustration 1

Stabile osteosynthesis in a transverse fracture of the lower third. Spread nail with inclined plane.

Illustration 2

Transverse fracture in the middle of the leg. (Spread nail).

Illustration 3

Oblique fracture of the lower third of the tibia after removal of the spread nail.

Illustration 4

Oblique fracture in the lower third. Spread nail with inclined plane. Stabile osteosynthesis

Illustration 5

Double fracture of the tibia. Treated with double nail.

Illustration 6

Condition after healing of a nailed double fracture.

Illustration 7

Cloud callus, a plentiful callus formation which appears weak in the X-ray and begins to form after a very short time.

Illustration 8

Trivial callus formation with ideal reposition and quick healing. Most often found in nailed fractures of the lower leg

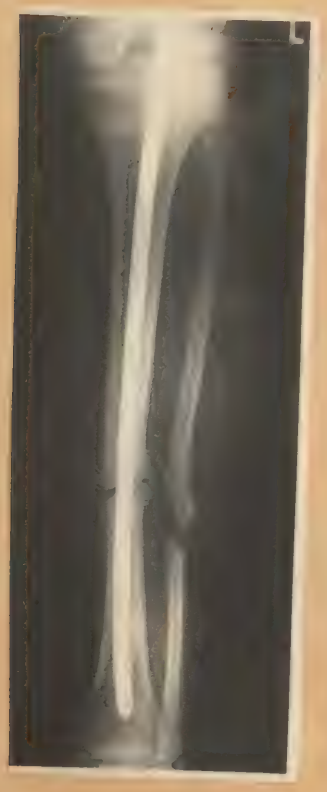


Illustration 9

Extensive periosteal reaction with a juvenile patient. Periosteal reaction hardly visible on the copy.

Illuatration 10

Favored callus formation of the concave side with a slight valgus position of the lower leg.

Illustration 11

Pseudarthrosis in the lower third of the right tibia.

Illustration 12

The same fracture after treatment with especially strong spread nail with inclined plane.

Illustration 13

Nailing of a pseudarthrosis after oblique freshening.

Illustration 14

By attempting to drive the nails in with force the fracture bent and the surfaces did not come together.

Illustration 15

Fresh fracture of the femur.

Illustration 16

Same fracture after nailing. (bilateral nearly equal fracture of a child, 7 years old)

Illustration 17

Condition after healing, shortly before the removal of the nail.

Illustration 18

Fracture of the femur, with a large piece of the corticalis broken out. Fracture was not stable. Fixation through additional wire-extension.

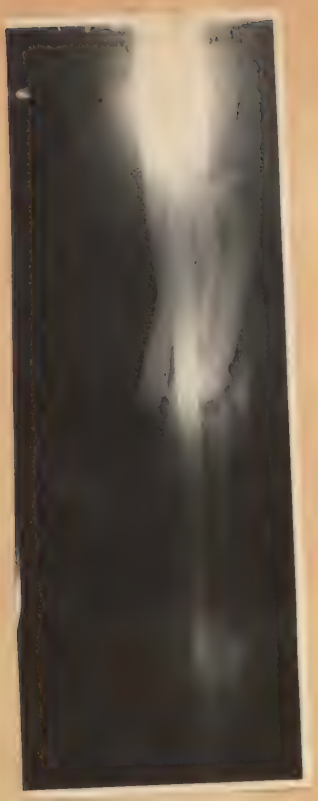


Illustration 19

Comminuted fracture of the femur. Additional fixation was necessary (wire-extension)

Illustration 20

Gun-shot fracture of the femur.

Illustration 21

Same fracture after marrow-nailing. Additional wire-extension necessary. Fracture healed with 3 centimeters shortening.

Illustration 22

Spontaneous fracture of the femur.

Illustration 23

Same fracture. Condition after nailing. The nailing was performed without exposing the fracture.

Illustration 24

Metastasis in the femur. Condition after marrow-nailing.

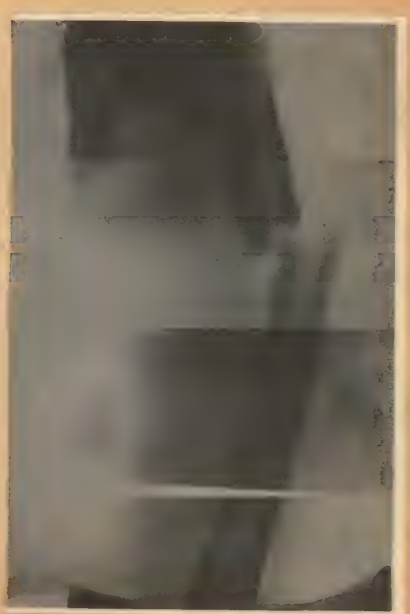


Illustration 25
Spontaneous fracture in the femur.

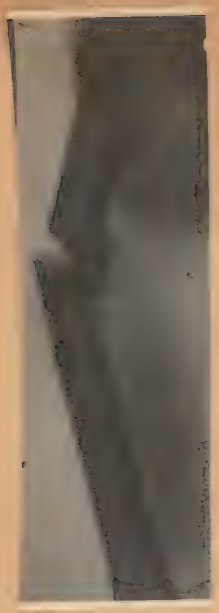


Illustration 26

Condition after a wire-extension lasting for 3½ months.

Illustration 27

Condition after marrow nailing

Illustration 28

After 5 weeks, distinct sign of a callus formation at the outside of the fracture.

Illustration 29

Angulation of the axis in the form of a varus. The leg was shortened 5½ centimeters.

Page 35 missing

Illustration 33

Same fracture. Healing pseudarthrosis with a bone graft from a rib.

Illustration 34

Large metastasis in the left arm above the elbow from a bronchial carcinoma. Condition after marrow nailing.

Illustration 35

Fracture of the ulna, nailed primarily with nail placed ideally.

Ill. 36a

Illustration 36 and 36a

Pseudarthrosis of the ulna. Nail broken at the site of the fracture and a distinctly visible cleft in the ulna.

a) Conditions after nailing of the pseudarthrosis with a graft from the tibia inserted in addition.

(Editors Note: Illustration 37/38 is missing.)

Illustration 39

Defect gun-shot fracture of the ulna. The 4 centimeters defect was bridged over with a bony bar. Patient got up after 2 days.

Illustration 40

Same fracture. Changes in the area of the bony bar occurred.

Illustration 41

A pseudarthrosis developed in the area of the bony bar.

Illustration 42

Isolated defect pseudarthrosis. A freshly resected piece of fibula was placed between the freshened ends of the fragments and kept in place while "strung" on the marrow nail.

Illustration 43

When the corresponding bone was in a wrong position an osteotomy was performed on that one too.

Illustration 44

Condition after correction of the wrong position and marrow-nailing.

Illustration 45

Condition after the nailing of a suppurating fracture.

Illustration 46

Same fracture. 9 months after the nailing, the fracture was bridged over with bone and the nail was removed.

Illustration 47

Gun-shot fracture of the femur. Comminuted fracture.

Illustration 48

Condition after marrow-nailing of a comminuted fracture. Ideal reposition.

Illustration 49

Same fracture. Fracture healed. Marrow-nail removed. Fistula of the marrow-cavity.

Illustration 50

Condition after the nailing of a healing suppurating fracture of the [illegible] the elbow.

Illustration 51

Healed fracture after removal of the nail. Ideal reposition.

Special Print from

"Archiv f r Clinical Surgery" Vol.205, 3 part.1944.pg.455-474

Edition Springer, Berlin W 9

(From the Surgical University Clinic, Kiel.)

(Director: Prof. Dr. A. W. FISCHER)

COMPARATIVE INVESTIGATIONS CONCERNING THE COURSE OF FRACTURE HEALING WITH THE MARROW-NAIL (KUENTSCHER) AND WITH PLASTER CASTS

by

Doz. Dr. med. habil. HEINZ GRIESSMANN and Dr. med. HORST REICH

Assistants of the clinic

With 13 Illustrations in the text*

* The microscopical views could not be reproduced, an attempt had been made to trace the X-rays on the stencils.

(Submitted September 1943)

Translation prepared by:

U. S. Naval Technical Unit, Europe, (Medical Section)
Office of Naval Advisor
Office of Military Government (U. S.)

In spite of numerous experiments with animals and investigations in men the question has not yet been settled as to which tissues are most important to the healing of bone fractures, particularly, which tissue is the decisive element in the union of the fragments.

DUHAMEL was the first to recognize the bone-constructing efficiency of the periosteum. Later DUPUYTREN reinforced this concept and deduced that not only does the periosteum form callus, but also the fracture surfaces of the bone itself and sometimes even the surrounding soft-parts take part in the process.

According to the investigations up to the present time it is assumed that the formation of callus depends on the activity of cells originating from different tissues, but always of mesenchymal origin. Every mesenchymal tissue is able to produce bone under certain conditions and so the problem of callus-formation has become a problem of differentiation.

At the present we speak of the many potentialities of the mesenchymal germinating tissue, from which connective tissue, cartilage and bone can be differentiated.

The activity of the cells is directed by different factors, which may be physical, chemical, hormonal, endocrine and alimentary.

We do not intend to discuss the numerous chemical, hormonal, endocrine, and alimentary factors, which may disturb the healing of a bone-fracture, as it would be too lengthy for this article. But it is necessary to point to the physical factors in the healing of a fracture, as there is no question that these factors are of decisive importance.

The ROUX law says, that forces pressing the fragments together act as formative stimulants on the bone substance, but forces causing lateral displacement act destructively. Therefore, ROUX has pointed out that with the traction treatment for fractures pseudarthroses are more liable to develop.

As KROMPECHER showed the normal development of a bone will be chondrogen when influenced by pressure, desmogen when traction force is acting, and angiogen when neither of these forces acts. KROMPECHER examined the bones of the lower legs of dogs treated in compressing and traction apparatuses to determine the reaction of the bone regeneration to these factors. His observation on normal bone development proved that under the effect of pressure cartilaginous callus is formed from which bone is produced. Under the effect of traction he found a change of the undifferentiated mesenchymal germative-tissue into temporary connective tissue callus. Additional cells lie between the collagen fibrils. These develop into osteoblasts which surround the connective tissue bundles with bone substance as the growth of bone progresses. He came to the conclusion that a cartilaginous callus is formed, which, when the fracture ends are pressed against one another with slight force during the healing process, changes into chondric bone-callus as the chondric bone-formation progresses. This chondric bone-callus is structurally especially capable of withstanding pressure. If, however, the ends of the fragments are continuously separated from one another, by traction during the healing process, connective tissue callus will be formed. The desmal bone thus developed is rather compact, but the connective tissue kind of bone-healing is structurally unable to withstand pressure. KROMPECHER tried to support his opinion by the findings in a fracture healed with

angulation at the site of fracture. The regeneration of the concave side which was under pressure was endochondral, on the convex side, however, which was under traction, desmal. BIEBL found in ideally corrected wire-sutured fractures of the femur a strong formation of callus on the rear and inner side of the femur, and slight callus formation on the front and outer side. He explains these observations by the formation of callus being favorably influenced by pressure on the concave side whereas the formation of callus is hindered by traction force on the convex side.

But the problem is not so simple as the investigations of KROMPECHER make it appear. The point of view of present day pathologists is, that desmal healing of the fracture is considered to be normal, at least in adults, and cartilaginous callus is created only as a result of special conditions (LAUCHE). Even with fractures healed in a plaster cast under pressure, desmal healing is considered to be normal. This assumption is contrary to that of KROMPECHER. The question then arises whether it is possible to obtain an experimental condition which permits only one of the forces to act either pressure or traction and which eliminates all forces tending to cause lateral displacement. It is unanimously acknowledged that these latter forces are harmful, and therefore they should be eliminated as much as possible by the therapeutic measures.

KUENTSCHER was able to prove with his procedure of the extension lines that the LOOSER reconstruction zones are found exactly at the places of strongest traction-tension, the peak of traction-tension. If, however, even the healed bone is especially sensitive to traction stress, then the growing bone or callus must be effected all the more by this same force.

PAUWELS has convincingly proved in fractures of the neck of femur how much mechanical factors influence the healing of bone fractures. He further showed that this mechanical problem can be solved with suitable counter-measures. In the case of a fracture of the neck of the femur the mechanical stress may act as a free lateral displacement force according to the angle of inclination of the planes of the fragments to one another and thus prevent bony healing, or acting as functional stress may bring the fracture to bony healing. Thus PAUWELS has demonstrated in case of a great angle of inclination caused by a wedge shaped subtrochanteric resection of the upper portion of the femur, that the action of the forces can be changed in such a way, that instead of a freely acting lateral displacement force a functional pressure comes into effect. Thus bony healing, even of pseudarthrotic fractures of femur-necks can be obtained.

When we observe our present methods of treatment from these mechanical points of view we can state that none of the procedures fulfills the ideal conditions which are required for an undisturbed course of healing, namely the elimination of all harmful distraction forces as well as forces causing lateral displacement. It has to be mentioned that even the KROMPECHER experimental distraction- and contraction-apparatus is not able to eliminate completely those forces causing lateral displacement. BLOCK, who made experiments similar to these of KROMPECHER, also assumes that these forces always disturb the conditions of the experiments.

In the extension-treatment harmful distraction forces can act when the extension is not applied in the correct amount. All the other methods prevent much of the harmful forces tending to produce lateral displacement, especially the plaster-cast and the ambulatory

cast, but they never eliminate them completely. Only the marrow-nailing procedure, introduced by KUENTSCHER, enables the surgeon to obtain complete rest in those fractures, which are suitable for this method, and eliminates all of these undesirable forces causing lateral displacement which hinder callus formation, and permits the forces pressing the fragments together to act freely and thus leads to the healing of the fracture. Cases especially suitable for marrow-nailing are the transverse fractures of the long tube-bones located in the middle of the shaft in which a "stabile osteosynthesis" (KUENTSCHER) may be obtained by the marrow-nail acting as an internal splint.

One might object that the marrow-nail destroys the entire marrow in the bone over a large area and this would delay the reconstruction of the bone. But it has to be remembered that the marrow-nail does not act like a piston in a syringe because of its being V-shaped and therefore does not push all the marrow out of the cavity when inserted, but only a small portion of it is displaced and squeezed out through the fracture cleft. Furthermore, experience showed that in cases ideally suitable for marrow-nailing the healing of the bone is not disturbed. On the contrary a quicker consolidation of the bone fracture is achieved. The marrow-nail made of V2A-steel, neither hinders callus formation as a foreign body, nor is it harmful to the tissues.

From all recent clinical and X-ray investigations, finally also from the histological examinations of KUENTSCHER, definite pictures were obtained of the situation at various stages which permit one to observe the events in the tissues, but did not give an explanation concerning the course of these events in detail.

By means of experiments in dogs the course of healing was investigated in fractures treated with a plaster cast and those treated with a marrow-nail and the changes occurring in the tissues were recorded.

PLAN OF THE EXPERIMENTS

8 adult dogs of almost similar weight were used for the experiments. In all the animals the tibia was fractured in the middle of the shaft subcutaneously, by means of an osteoclast, in such a way that the fragments were left in their anatomical position whenever possible, to prevent a rough dislocation in the fractures which were not to be treated with a marrow-nail, and thus obtaining rather similar conditions for the experiment. Ill. 1 shows in lateral position the fractures of the tibia approximately in the middle of the shaft treated with and without the marrow-nail, experiment 1.

To save space we did not add further X-ray illustrations. The A-P X-rays of experimental pair No. 1, killed 7 days after the fracture of the leg, showed an anatomically ideal position for the entire period of the experiment.

The plaster casts were always applied so that they extended over both the adjacent joints. X-ray pictures of all the dogs were made every 8 days. The first pair of dogs were killed after 7 days, the second pair at 14 days, the third pair at 5 weeks, the fourth pair at 6½ weeks after the leg was broken.

All operations were done under somnifone-ether narcosis.

The marrow-nailing was made with V-shaped V2A-marrow-nails.

As we expected, the anatomic position of the fragments could not be maintained as at the beginning of the experiment in those animals treated with plaster casts. An effort was made to correct the position by changing the casts. We will report on the details of the dislocation when discussing the respective pairs of dogs. Thus the conditions were similar to those occurring with the usual methods of fracture-treatment, i.e. the forces tending to cause lateral displacement which are harmful to the healing of the fracture could not be eliminated in the animals treated with the cast but in the fractures treated with the marrow-nail only those forces pressing the fragments together acted from the beginning.

FINDINGS:

1. The first couple of dogs, examined 7 days after the fract showed an ideal position of the fragments in the X-ray picture (Ill. but no formation of callus was observed. The fracture cleft was distinctly visible in both bones.

After the removal of the soft parts surrounding the bone neith of the broken bones showed anything unusual to macroscopic examination. In both, the site of the fracture-hematoma could be seen. Comparable sections of the broken bones were taken and these were examined microscopically in the cross-section. The entire bone (including the fibula) was sectioned from the head of the tibia to the ankle to make it possible to observe the areas at some distance from the fracture site. For comparison the uninjured bone of the other side was examined at the same level. The bone-particles were dyed with hemotoxylin-eosin after the method of VAN GIESON. The following reports always relate to analogous parts of the bones.

Microscopic examinations of the tissue of the 7 day old Fracture in the leg, treated with plaster - cast.

The bone of the uninjured lower leg shows a normal structure. The bone of the broken leg shows above as well as below the fracture site, at a distance of 6 cms, a very slight reaction in the periosteum A slight swelling of the lamellas is found, and the periosteal vessels are increased in number in comparison with the healthy bone. No perivascular reaction is detected. The periosteum is a thin lamella-like tube next to the compacta, as is usually found in healthy bones. The compacta shows an orderly formation without any remarkable signs of resorption. Some widened HAVERSIAN canals are found in which no destruction of the compacta has taken place. (Ill. 2)

The bone-marrow consists of fat-marrow. No other findings worth noting are seen in the marrow. No reaction in the connective tissue of the vessels was seen. In the area close (3 cms) to the fracture a more marked swelling of the periosteal tissue is found associated with an increase of the number of fibrils. The number of vessels is also increased. The compacta and the marrow are unchanged. Quite close to the fracture site (1 cm) a formation of osteoidal spicules arises in the entire periosteal tube, surrounded by strong, well stained zones osteoblasts. On the concave side of the bones i.e. on the side of strongest pressure, the formation of osteoids is the most complete. These osteoidal spicules are arranged almost exactly radially. (The position of the fracture was ideal during the entire period of the experiment!). Their network is penetrated by blood-vessels, their gelatinous substance, in which no collagen fibrils were detected, is stained slightly blueish by hematoxylin-eosin. In these places the compacta shows only slight lacunary resorption, the bone-marrow, however, shows a beginning bone-reconstruction in the

form of fine osteoide spicules appearing like those of the periosteum. Organization of the fracture hematoma can be detected paraosteally. The fracture site itself shows paraosteally a connective tissue arranged longitudinally with numerous vessels and perivascular infiltrates. Next to it comes a high layer of osteoids, stained a faint blue with hematoxylin-eosin. The osteoid-layer shows a network construction. Furthermore the osteoid-layer is often interrupted by deposits of blood-pigment and tissue-debris. Osteoid spicules extend almost to the compacta, which in the immediate area of the fracture shows more resorption. In the marrow a rather active osteoid-formation is found, especially in the peripheral marrow area. Intermediary fresh connective tissue is seen changing into osteoid, the tissue next to the marrow being very edematous. The findings below the fracture site are similar to those found above it.

Examination of the tissue of the 7 day old fracture in the leg, treated with a marrow-nail.

The uninjured bone does not show any unusual findings. At a distance of 6 cms from the fracture analogous to the same area as the fracture treated with the cast, we found, in this case, even this early, a marked periosteal reaction in the way of a formation of osteoid spicules with a definite swelling of the periosteal substance and proliferation of the vessels. In the compacta only a very few HAVERSIAN canals are distended and contain edema fluid. Aside from this the compacta is unchanged. In a surprising manner a tissue similar to connective tissue is found compressing the marrow around the osteoid. The fresh osteoid lies around the nail slot in a thin shell-like layer (Ill. 4).

Closer to the fracture site (3 cms) the osteoid substance formed from the periosteum shows a considerable increase of height. Just as seen 6 cms above and below the fracture site, it is arranged in an orderly radial pattern of spicules (viz. Ill. 5 & 6). The compacta appears as it does more distant from the fracture site and does not show any remarkable evidence of resorption. Around the nail-bed there is a coat of connective tissue constructed by the marrow with fresh osteoid spicules arranged more or less in thin layers. There are no symptoms of infection. The closer the sections are to the fracture site, the higher is the osteoid layer of the periosteum, with a preference for the concave side of the bone. Also here in the compacta there are no marked changes. In the fracture-cleft itself, besides a high periosteal osteoidal layer, beginning necrosis of the ends of the fragments is to be seen, appearing as a spreading edema. The bone seems to have been nibbled and no bone cells are to be seen. Cells dissolving the bone were not found. The fracture cleft is bridged over by connective tissue. There is no development of osteoid in that place, only a condensation and swelling of the connective tissue fibres with proliferation of the vessels. A strong reaction of the connective tissue is seen paraosteally but only by the proliferation of vessels, again strongest at the concave side.

Comparing the staining quality of the osteoid substance of this bone with the one treated with the cast, it appears that in the marrow-nailed bone the stain is more intensively blue. This may be caused by a greater precipitation of calcium-salts in this fracture.

COMPARATIVE SURVEY:

In the fracture kept at rest by means of the cast no periosteal reaction occurred distant from the fracture site, butin the marrow-

nailed fracture a distinct osteoid-formation can be detected at a distance of as much as 6 cms. Only close to the fracture site does the periosteum start to form osteoid in the fracture treated with the plaster-cast, the osteoid being as thick as it is in the same place in the nailed fracture. In both the cases the osteoid shows a regular construction, only in the area of the fracture treated with the cast the osteoid-formation appears more irregular than the corresponding place in the nailed fracture. The compacta of the fracture treated with the cast shows more resorption; the marrow starts forming a marrow-osteoid in the immediate area of the fracture. The marrow-nailed fracture, however, reacts with a formation of marrow-osteoid at a great distance from the fracture (6 cms). The nail-s is surrounded by connective tissue. In both the tibiae the concave side of the bone which is under the strongest pressure shows a more prominent formation of osteoid. In comparing these findings it has to be taken into consideration that the anatomical position of the fragments of the fracture treated with the cast was maintained during the entire period of the experiment, thus stronger forces tending to cause lateral displacement were eliminated.

2. The second pair of dogs, examined 14 days after the fracture showed in the X-ray a transverse fracture in the middle of the tibia and fibula. In the marrow-nailed fracture an ideal position of the fragments was maintained during the period of the experiment. The leg fracture kept at rest with a plaster-cast also showed an ideal position in the beginning, but after 8 days a dislocation occurred in a lateral direction for almost as much as the diameter of the shaft. This latter position was maintained until the end of the experiment. After the experiment a spindle-shaped callus-formation was observed in the marrow-nailed fracture extending over 5 cms in the tibia which was 16.5 cms long. The cast-treated fracture showed only slight evidence of callus-formation in the X-ray picture. Both fractures were still loose.

The examination of the bones was performed in the same way as in the first pair of dogs.

Microscopic examination of the tissue of the 14 day old fracture in the leg, treated with the plaster-cast.

The bones of the uninjured legs are without any pathological findings. At a distance of 9.5 cms and 6.5 cms from the fracture the periosteum does not show irregularities except a slightly thicker outer general layer and vessel infiltration. The compacta shows only a low grade irregular resorption. The marrow is without findings. At a distance of 3½ cms from the site of fracture we find a high periosteal callus-formation. It is surprising that also paraosteally a strong connective tissue-like reaction can be seen, especially between the surrounding muscle bundles. The osteoidal spicules show fresh calcium infiltration identifiable by the light fine-grained color. Its arrangement appears irregular. It lacks the impressive radial-stripped arrangement verticle to the compacta as was found in the marrow-nailed or ideally repositioned fracture of the first pair of dogs. The compacta is without findings, except slight irregular resorption, at this level (3½ cms from the site of fracture). However, a rather strong formation of callus is found in the marrow. Near the fracture site the compacta participates in the increased disorganisation. Resorptive processes are found on damaged bone particles. The formation of marrow-callus is very active. In the osteoid spicules a beginning calcification can be detected. The general impression is that the tissues at the fracture site appear irregularly arranged. Besides fresh calcified osteoid of the periosteum we find cartilaginous

tissue and the beginning change from cartilage into bone-tissue can be observed. The periosteal bone-deposit in the fracture-site is of various heights. The periosteal callus is frequently interrupted by cartilage-islands which are forming bone by themselves. Furthermore, a tense fascial tissue is seen containing abundant nucleae. In general there is no uniform tissue reaction in the periosteal tube. In the fresh callus of the periosteum and of the marrow evidences of disorganization can be found. The intermediary callus originates from the marrow as well as from the periosteum. As Ill. 7 shows the periosteal osteoid grows into the fracture cleft and unites there with an osteoid network formed by the marrow.

Microscopic examination of the tissue of the 14 day old marrow-nailed fracture in the leg.

The uninjured bone is without pathological changes. Marrow-nailed leg-bone: The periosteal callus formation starts even at a distance of 9 cms from the fracture, therefore immediately below the knee-joint. Starting at this point the calcifying periosteal osteoid-layer is of increasing thickness up to the site of fracture and is the most heavy in the area of the fracture. Ill. 8, which represents a transverse section at a level of 6 cms above the fracture site, shows the osteoidal spicules well arranged in a radial direction. They represent the stage of change from osteoid into genuine bone-substance. Because of that we find areas of osteoid which still show osteoblasts, especially in the peripheral area; but for the most part, preferably close to the compacta, it has already changed into genuine periosteally formed bone, which is proved by the small bodies of bone now observed. The greatest degree of calcification is found close to the compacta (see Ill. 9). The compacta shows at all levels only a slight irregular resorption in the peripheral areas. The marrow contains some genuine marrow-bone, which surrounds the tissue of the nail-bed arranged more or less in layers (Ill. 10). This marrow-bone is found for the entire length of the nail; at some spots of the marrow a resorptive activity appears.

COMPARATIVE SURVEY:

In the X-ray a distinct spindle-shaped callus-formation can be detected around the fracture cleft in the marrow-nailed bones of the lower leg; in the fractures treated with the plaster-cast only slight callus formation can be found close to the fracture cleft.

In the microscopic examination the great difference between the callus formation is especially surprising. The cast-treated fracture shows periosteally formed callus only in close proximity of the fracture-cleft, but in the nailed fracture even at a considerable distance from the fracture cleft, immediately below the knee-joint. In the comparable level of the leg treated with the cast no periosteal reaction of any consequence can be detected, and in the area of the fracture treated with a cast we find an irregular formation of tissue. Besides the periosteally formed callus one can observe considerable cartilage changing into bone and much compact connective tissue. In the marrow-nailed fracture the fracture-site shows a perfectly regular tissue-arrangement. Only a calcifying high osteoid tissue is found arising from the periosteum. It shows some osteoblasts peripherally. Near the compacta it has already changed into bone particles.

In both fractures a moderate irregular resorption is found in the compacta.

The marrow of the fracture treated with the cast shows callus produced from the marrow only in the immediate area of the fracture. The marrow-nailed bone of the lower leg shows, over the entire extent of the nail-bed, a rather strong callus formation, and it is astonishing that this callus is much more developed than in the bone treated with the cast. This callus even shows the appearance of completed bone.

3. The third pair of dogs, examined 5 weeks after the fracture of the leg bones, shows a transverse fracture in the tibia and fibul of the middle of the shaft. In the marrow-nailed fracture an ideal position of the fragments was maintained during the period of the experiment. The fracture treated with a plaster-cast showed at first a slight dislocation laterally for almost 1/3 of the diameter of the shaft, 4 weeks later a further slight dislocation of the axis had occurred. The observation of the callus formation by means of X-rays was rendered difficult because of the plaster-cast. Beginning callus formation could definitely be detected only after 3 weeks. After 5 weeks there was good callus formation and bony healing of the fracture. The fracture cleft was still distinctly visible. In the marrow-nailed fracture distinct spindle-shaped callus formation was formed after 3 weeks. After 5 weeks there was bony fixation of the fracture and the cleft of the fracture was hardly visible (Ill. 11).

The examination of the bones was made in the same way as in the other experiments.

The tissues of both fractures are 5 weeks old and in a more advanced stage. Therefore we do not give a detailed description here. Our findings are described in the comparative survey.

COMPARATIVE SURVEY:

In both dogs bony healing of the fractures was achieved after 5 weeks. The marrow-nailed fracture healed in anatomically ideal position. The fracture treated with the cast healed with a lateral dislocation and angulation. As in experiment 2 we also found here in the cast-treated fracture an abundant callus formation in the area of the fracture. The appearance of the tissue is, compared with that in the marrow-nailed bone, rather irregular. In the area of the fracture we find excessive bone-callus originating from the periosteum, connective tissue, and cartilage. In the area of the fracture abundant cartilaginous tissue is observed; there are changes from cartilage into bone-tissue, irregular areas of calcification in the cartilage and finally a considerable formation of connective tissue in the form of an almost rigid fascial tissue. If there was not so much periosteal callus all this might lead to the conclusion that a pseudarthrosis had been formed, as there is so much connective tissue. The periosteal bone deposit begins only in the immediate area of the fracture. Even the formation of marrow-callus begins in that area. These with periosteal callus contribute to the intermediary stabilization. The compacta shows a stronger resorption especially at the fracture-site. We have the same finding in the area of the periosteally formed callus and the marrow-callus.

The marrow-nailed fracture shows a considerable variation, generally to be considered as the result of the inner splinting of the fracture. In this way favorable conditions for the healing of the fracture was achieved. This may be seen by the fact that in the microscopical examination an absolutely regular arrangement in both the callus- and bone-formation is achieved. No considerable paraosteal reaction is seen. The periosteum is the chief factor in

the consolidation of the fracture. A new periosteal bone is formed surrounding the fracture site, like a coat. Its bone spicules are arranged radially in the direction of the compacta. At all points we see well formed fresh bone, the compacta being arranged in layers. This bone deposit however is, by no means, as high as in the comparable parts of the cast-treated fracture. Its structure is much more regular because the periosteally formed bone-spicules are arranged radially. At all levels we find only this radially arranged bone, which is uniformly calcified. Other kinds of tissue are not seen. As in the cast-treated fracture we find here also marked resorptive symptoms in the way of an irregular resorption in the newly formed periosteal bone, in the compacta, and in the marrow-bone, over the entire extent of the bone, especially in the area close to the fracture.

4. The fourth pair of dogs, examined 6½ weeks after the fractu of the leg-bones, showed a transverse fracture in the middle of the shaft of the tibia and the fibula. Ideal position of the fragments in the marrow-nailed bone during the period of the experiment, and a stabile bony healing was achieved after 6½ weeks. The fracture cleft was only slightly visible. During the experiment the fractu treated with plaster-cast showed a lateral displacement of half th diameter of the shaft and a rather marked angulation (recurvation). A good formation of callus was achieved and the fracture cleft was still visible after the lapse of 6½ weeks.

Examination of the bones was made as in the other experiments.

Microscopic examination of the tissue of the 6½ weeks old fracture in the leg treated with the plaster-cast.

The uninjured bone did not show any changes. A rather strong periosteal callus-formation is found (about 6 cms distant from the fracture-site). At 3 cms distance from the fracture site an additional strong paraosteal callus formation is seen. The periosteal bone-tissue is not constructed radially. Small cartilage-islands, located between the periosteal bone-spicules, are partially calcified. Paraosteally a very distinct formation of cartilage is found. The infiltration of calcium varies and an extensive formation of connective tissue is seen in the form of a rather compact fibrous tissue. Rather marked resorptive symptoms can be seen in the periosteal and paraosteal bone, as well as in the compacta, with symptoms of a disorganization of the tissue. One cm distant from the fracture-site and in the area of the fracture itself the formation of cartilage and connective tissue is more distinct.(Ill.12) A good formation of periosteal callus can be observed, the spicules of which, for the most part, are irregularily arranged. The compacta shows a marked irregular resorption in the fracture site itself, especially around the border in the direction of the bone of periosteal origin. There are different degrees of bone formation, going through osteoid and cartilaginous phases. In the fracture cleft there is sufficient connective tissue with a beginning of bone formation.

Microscopic examination of the tissue of the 6½ weeks old marrow-nailed fracture in the lower leg.

To prevent repetition we summarize the findings.

As far as 6 cms above and below the fracture site in the 17 cms long tibia we see a uniform picture of a normally constructed bone-shell. The fracture cleft is bridged over and consistently shows

evidence of rebuilding. The same evidences of reconstruction are also to be found in the marginal parts of the compacta. The reconstruction of the bone is strongest on the side of the physiologically concave curvative of the leg-bones. The outer general layer of the periosteum can be seen. An ideal bony healing is achieved in the area of the fracture site in such a way that the inner layers of the new periosteal bone are well attached to the old compacta. A regular arrangement of the osteons is seen. In a very few places we find some small calcified bone islands in the periosteal bone-shell. Resorptive symptoms are seen in the compacta, in the marrow-bone and in the periosteally formed bone. The new periosteal bone is better developed than the comparable area in the case treated with the cast. Its construction is absolutely uniform (Ill. 13).

COMPARATIVE SURVEY:

Both fractures showed bony fixation after 6½ weeks. The marrow-nailed fracture healed in an anatomically ideal position as in all the experiments. The cast-treated fracture healed in lateral and axial displacement. In the marrow-nailed fracture the X-ray showed the same extent of the spindle-shaped calcified callus as in the experiment 3. In the fracture treated with the plaster-cast the callus formation was also considerable. No spindle-shaped callus was found, the margin of this calcified callus is irregular. The periosteal reaction observed only in this case (6 cms distant from the fracture site) has to be considered as the result of an extensive damaging of the periosteum caused by a pronounced dislocation of the fracture. The periosteally formed bone is constructed irregularly and infiltrated by cartilaginous tissue which is calcified to a varying degree. Paraosteally plenty of cartilaginous and dense fibrous tissue is seen. The findings correspond to those of experiment 3.

The periosteally formed bone of the marrow-nailed fracture still shows very distinctly the radial arrangement of the former osteoid spicules. Its inner layers are already built into the compacta. Paraosteally no reaction is seen, except small catilage islands. Formation of marrow-callus is observed only in the area of the fracture in the case treated with the cast. However, in the nailed fracture the callus can be seen in the entire length of the nail surrounding the nail-bed.

The resorption processes are more evident in the cast-treated fracture than in the marrow-nailed fracture. The reason for this is the dislocation and insufficient fixation of the cast-treated fracture. In this experiment the evidence of resorption is further developed in both fractures. This is due to the length of time the fractures have existed.

SUMMARY OF ALL THE FINDINGS:

In experiments with animals an attempt was made to reproduce the arrangements similar to those in human beings, and the healing process of fractures treated with plaster-cast and those with the marrow-nailing was compared at different stages.

In the treatment of fractures with a plaster-cast it was observed that besides the bone-constructive effect of the bone itself, the paraosteal tissue has participated extensively in the stabilization of the bone. In the marrow-nailed fracture however the paraosteal tissue did not take any active part. The experiments showed that periosteum is of utmost importance for the healing of bone-fractures.

In the marrow-nailed fractures the periosteum shows considerable bone reconstruction in the area distant from the fracture site. A periosteal reaction could not be detected at the corresponding area of the cast-treated fracture.

In the areas of the fractures treated with the two methods, a good periosteal bone formation is found, but it is remarkable that the callus of the cast-treated fracture shows an irregular picture, the marrow-nailed fracture however shows a very regular radial construction.

In both cases the callus shows evidence of spotty resorption after the lapse of a certain time. This starts earlier with the cast-treated fracture. Here the symptoms can be seen more distinctly and in a larger area of the bone.

In the marrow-nailed fractures the bone marrow shows marrow-callus along the entire length of the nail. The nail-bed itself is surrounded by a coat of connective tissue, i.e. it is demarcated by connective tissue. In the cast-treated fractures a marrow-callus formation is found only in the very area of the fracture, acting in the way of an intermediate consolidation of the fragments together with the periosteum.

The callus, formed in marrow-nailed cases, is of an absolutely regular arrangement and will result in a good stabilization of the fracture. Therefore it is of great value with regard to the reconstruction of the bone and it is definitely superior to the marrow formed in cast-treated fractures. Not the quantity, but the quality of the callus is the decisive factor determining its structural value.

The callus in marrow-nailed fractures, which is structurally better, results from the elimination of all the harmful factors which disturb the healing, such as distraction forces, and these forces causing lateral displacement. Only pressure comes into effect and it is the only force advantageous for the formation of callus.

KROMPECHER was of the opinion that cartilaginous callus is formed by pressure. Our experiments with the fixation of the fracture by the marrow-nail, which eliminates all forces causing lateral displacement, have proven that a desmal callus is formed under pressure. This corresponds to the other findings of the origin of bone-callus. It is possible, that KROMPECHER could not eliminate all lateral displacement forces during his experiments. The great quantity of cartilaginous tissue, especially parosteally, in our fractures fixed with the plaster-cast, in which not all of the lateral displacement forces could be eliminated, shows that a cartilaginous tissue is produced only under special conditions, namely when it is not possible to eliminate these harmful forces.

The total elimination of the lateral displacement forces during the healing process of fractures in the shaft of tube-bones can be achieved only by means of the KUENTSCHER marrow-nailing method.

The stronger the pressure forces are, the greater will be the formation of callus. This can be seen at the place of the strongest physiological concave curvature of the bone. The periosteally formed callus rather distant from the fracture and the extensive formation of marrow-callus around the nail slot may be explained by the pressure or the chemical stimulation of the inserted nail upon the surrounding tissue (KUENTSCHER).

B I B L I O G R A P H Y :

Illustrations:

1. Lateral view of a tibia-fracture in the middle of the shaft of experiment 1. Position of the fractures 7 days after the end of the experiment.

2. 7 days old, cast-treated fracture, at a distance of 6 cms from the fracture site. No periosteal reaction.

3. 7 days old, marrow-nailed fracture. At the level of the fracture. High periosteal osteoid with surrounding connective tissue reaction. Pronounced irregular resorption in the compacta.

4. 7 days old, marrow-nailed fracture, at a distance of 6 cms from the site of fracture. Periosteal osteoid-formation. No irregular resorption of the compacta. Marrow-osteoid. Fibrous tissue around the nail slot.

5. 7 days old marrow-nailed fracture, at a distance of 3 cms from the fracture site. Well-arranged periosteal osteoid spicule system. Very slight evidence of resorption in the compacta.

6. 7 days old, marrow-nailed fracture, same area as Ill. 5 in higher magnification. Radial osteoid spicule-network of the periosteum with distinct margins of osteo-blasts. Resting compacta.

7. 14 days old, cast-treated fracture. The periosteal callus is growing into the intermediate area and extending into the network of the intermediary callus formed from marrow, a) periosteal callus, b) intermediar callus.

8. 14 days old marrow-nailed fracture, at a distance of 6 cms from the site of the fracture. High radially arranged periosteal osteoid.

9. 14 days old marrow-nailed fracture, at a distance of 6 cms from the site of the fracture. Close to the compacta the complete bone has already formed. In the areas of the margin of the compacta slight resorption is seen.

10. 14 days old marrow-nailed fracture, at a distance of 6 cms from the site of the fracture. Fibrosis of the nail-bed with distinct marrow-callus formation.

11. 5 weeks old marrow-nailed fracture, spindle-shaped callus.

12. 6½ weeks old cast-treated fracture. Site of fracture. Strong paraosteal reaction of the connective tissue and of the cartilaginous tissue. High periosteally formed bone with strong resorptive symptoms, also irregular resorption in compacta and marrow. Network like construction of the periosteal bone.

13. 6½ weeks old marrow-nailed fracture, at the fracture site. Regular construction of the periosteal bone. Inconsiderable resorption symptoms in the compacta, no paraosteal tissue-reaction, connective tissue like demarkation of the nail-bed.

B I B L I O G R A P H Y

BIEBL : Arch. klin. Chir. 194, 171

BLOCK : Die normale und gestoerte Knochenbruchheilung. Neue Deutsche Chirurgie, Bd.62, 1940.

FISCHER-REICH : Zbl. Chir. 1943, 299

KROMPECHER : Die Knochenbildung. Jena: Gustav Fischer 193[illegible]

KUENTSCHER : Arch. klin. Chir. 182, 489 (1935).

Chirurg 1936, 308, 440; 1942, H.6.
Chir. Kongr. 1940.

Zbl. Chir. 1940, 1145; 1941,1,857; 1942, 19[illegible]

LAUCHE : Handbuch der speziellen pathologischen Anat[illegible] und Histologie, Bd. IX, S. 204, 3. Teil.

MAATZ-REICH : Bruns' Beitr. 174, 358 (1943).

Note:

The illustrations accompanying the original text could not be reproduced with the available facilities since eleven of them are microphotographs. The legends for the illustrations will be found on the following page.

Illustration 1

Lateral view of a tibia-fracture in the middle of the shaft of experiment 1. Position of the fractures 7 days after the end of the experiment.

Illustration 11

5 weeks old marrow-nailed fracture, spindle-shaped callus.

Reprint from the

Zentralblatt fuer Chirurgie

70. Jahrgang, Nr. 11 - 1943

Verlag von Johann Ambrosius Barth in Leipzig

From the German Red Cross Clinic Clementinenhaus Hannover (Director: Prof.Dr.C. HAFBLER,) and the Surgical Department of the City Hospital Ricklingen (Deputy Director:Prof.Dr.C.HAFBLER)

THE STABLE FIXATION OF FRACTURES ("STABILE OSTEOSYNTHESIS") AND THEIR ECONOMIC SIGNIFICANCE

by

C. HAFBLER

Oberfeldarzt d. R. und beratender Chirurg beim Luftwaffenarzt

With 15 Illustrations*

* Facilities at hand did not permit the reproduction of the illustrations 3,6,9,12 and 15.

Translation prepared by:

U. S. Naval Technical Unit, Europe, (Medical Section)
Office of Naval Advisor
Office of Military Government (U. S.)

The objective of fracture treatment is the restoration of anatomical shape of the broken bone as early and as exactly as possible. This should be maintained until the healing of the fracture takes place without limiting the flexibility of the muscles and joints.

This ideal cannot be obtained by any conservative method, for the Plaster of Paris or the splint method involves a more or less prolonged limitation of motion of the joints next to the fracture. Also, the traction method does not permit a completely free flexibility of the joints and it by no means guarantees a complete fixation of the broken bone.

Thus surgeons tried some time ago to obtain the above mentioned objective by exposing the fracture in an operation, notching it or joining by pins or small splinters of bone after the method of a cabinet maker, winding wire around the bone, securing it with metal plates by screws and by similar methods. This osteosynthesis was not satisfactory, however, for the fixation of the broken bone was not so stable that one could eliminate the use of a bandage for keeping the effected part in a resting position. Thereby the harm by metal in the case of use of unsuitable material, and first of all the danger of an infection by the exposure of the fracture was so considerable that many authors, amongst them especially BOEHLER, completely denounced the foreign body osteosynthesis as a disastrous innovation. Even the supporters of this method advocated that it be used only in cases of the strongest indications and then only if conservative methods were not satisfactory.

During the last ten years a change of opinion has arisen on account of the extra articular nailing of fractures of the middle portion of the neck of the femur. The successes of this method have been so outstanding that it is undisputedly accepted as the method of choice today, even by the opponents of osteosynthesis.

Compared with the usual osteosynthesis there are important differences in case of the nailing of the neck of the femur:

A special shaped (three lamellae) nail is used for fixing the fracture, which is driven through the trochanter and the neck of the femur right up to the head. As a result of this design, together with the wedging which takes place after the nail is driven in, the fracture is given such stability by this method, that a fixation bandage is unnecessary and the patients are soon able to move and to use the injured limb again. KUNTSCHER has therefore described the nailing of the neck of the femur as "stabile osteosynthesis".

The second important difference is that the fracture cleft does not need to be exposed. The setting of the fracture is done subcutaneously and the wound required for the introduction of the nail is far distant from the fracture cleft and the hematoma of the fracture. The danger of an infection is thereby reduced to a minimun.

Infections of the operation wound sometimes arise but we have seen them only twice in more than 80 cases of marrow nailing. The infection, however, remains limited to the operation wound. Interruptions in the healing of the fracture as are observed unfortunately often in cases of other osteosynthesis, have never been seen by us and have not been described by other authors up to the present. If they really ever have arisen the number of these cases is insignificantly small.

Also, in cases of a nailing of the neck of the femur injuries due to metal are described. If one removes the nail in time no inconvenience will arise. This can be avoided by the use of nails of V2A-steel.

So the "stabile osteosynthesis" of the fracture of the neck of the femur practically fulfills all requirements for the treatment of a fracture mentioned in the beginning. With its introduction this particular fracture has lost many of its former horrors. The usually very high mortality rate has sunk considerably (to 4 - 10%). The pseudarthrosis, at one time arising almost regularly, can nowadays be observed only occasionally if the operation is done in time and the right technique is applied.

It is a great merit of KUENTSCHER that with his "marrow nailing" he developed a method in which the principle of the "stabile osteosynthesis" is also used for fractures of long bones.

A specially formed, V-shaped nail is introduced into the marrow cavity at some distance from the fracture and driven so deeply into the marrow cavity of the distal fragment, under X-ray control, that it completely fixes the fracture. The nail is so rigid, the fixing of the fracture so firm, that a bandage to keep the injured part in a resting condition is unnecessary. The patients can move the broken limb freely in all joints without pain and a short time later they can put weight on it again. Stiffening of the joints is therefore avoided. (see [11] 2,5,8,11 and 14).

But what about the dangers of this "stabile osteosynthesis" in cases of long bones?

Damages caused by metal: They need not be feared for the nail is manufactured of V2A-steel and is removed after the growth of the new bone during the healing process of the fracture.

Danger of infection: As the fracture cleft is not exposed, the fracture being repositioned subcutaneously and the introduction of the nail requires only a small wound far distant from the fracture, the danger is undoubtedly considerably less than in cases of other osteosyntheses. During the early days of the marrow nailing we have seen infections of the operation wound in 3 cases. The clinic of HIPL also reports observing this. These infections always remained localized. They have never been the cause of a removal of the nail or led to interruptions of the healing process. Considering that infections can be avoided by the use of sufficient skill and strict asepsis, the danger appears to be so small that it is of no importance compared with the advantages.

Foot note 1: In some cases of compound fractures and discharging wounds an infection of the marrow cavity and sequestrum formation have arisen, especially when technical errors were made. The drainage continued uninterrupted and free and the fractures healed solidly. No marrow phlegmon or acute osteomyelitis was observed.

Interruptions of the healing of the fractures: When one reads the technique described for the first time one almost becomes frightened and thinks of the failures of the use of pins made of small bone or ivory which are held especially responsible for the damage of the marrow and the endosteum. KUFNTSCHER has proven by experiments that on account of the shape of the nail no such damage has to be feared. First of all, the especially harmful factor of the plugging of the marrow when pins are used is eliminated in the marrow nailing method. The KUFNTSCHER-nail is strong enough to withstand the harmful bending and shearing effects (which the bone pin cannot do), it does not plug the marrow cavity, and in course of time it even loosens a bit so that the interlocking of the fragments will have the full effect of movement and use of the effected limb. These interlocking forces favor the formation and firmness of callus in a remarkable way, as is already known. Clinical experiences have already confirmed these theoretical and experimental results. Especially in the cases of fractures of the femur, one is repeatedly surprised at how rapidly the formation of callus can be observed in the X-ray.

So the marrow nailing method of KUFNTSCHER as a "stabile osteosynthesis" fulfills in an almost ideal way, all the requirements for the treatment of bone fractures. According to our experience we can fully confirm the point of view of the clinic of Kiel: "Every suitable fracture should be treated with the stabile osteosynthesis". For fractures of the shaft of the femur it is unconditionally the method of choice, superior to all others.

Some examples are now given to demonstrate the economic significance of the "stabile osteosynthesis" which is especially important in these days.

While in cases of a fracture of the neck of the femur even the best statistics indicate only a healing of 45% in case of treatment with the Plaster of Paris of WHITEMANN, the following percentages of practically complete recovery were obtained by the marrow nailing method, which can be used in a larger variety of cases than the Plaster of Paris: BOEHLER 74,4%, FELSENREICH in 73%, VOGELER in 70%, we ourselves in 72% of the cases of fresh fractures.

According to BOEHLER the average duration of hospital treatment without nailing amounted to 246 days, while with nailing it amounted to only 26 days since 1936, a number which completely agrees with our own and other authors experiences. This indicates a saving of 220 days, or RM 1100.-- if a cost of maintenance of RM 5.-- per day is assumed.

In the treatment of fractures of the shaft of the femur, BOEHLER reports an average period of treatment of 240 days in his clinic during the year of 1927, while in the cases treated outside the clinic it averaged 340 days.

The average period of treatment in the clinic amounted to 53 days when fractures of the femur were treated by the marrow nailing method, for the last three patients it averages only 35 days. This means again a saving of 200 to 300 days, of RM 1000.-- to RM 1500.-- cost of maintenance for each patient.

The duration of inability for work amounted, according to BOEHLER, to 625 days on the average for his own patients, while it amounted to an average of 1819 days for patients treated outside the clinic by the conservative methods. For our patients the longest time of inability to work amounted to 97 days (A Belgian worker of 60 years of age). After this time the fracture had firm bony healing and the nail was removed. In comparison to the admittedly good results of BOEHLER with the conservative method of treatment this means a saving of almost 1½ years of inability to work.

A larger series of statistics is not yet available and the number of our own cases of treatment is not large enough to permit a comparison between the final results of the "stabile osteosynthesis" and the conservative method of treatment. It can already be clearly recognized, however, that tremendous economic advantages can be obtained thereby. According to BOEHLER, the loss of less than 20% of the capacity of earning one's own living occurs in 5 out of 18 cases treated outside the accident clinic in the year of 1927. Only two patients were fully capable of earning their own living. Out of 14 cases of treatment in the accident clinic itself, the loss of the capacity of earning their own living amounted to less than 20% in 10 cases, out of which, however, only 4 were fully capable to earn their own living.. This was a success of which BOEHLER could properly be proud. In 17 cases of fractures of the femur where a marrow nailing was performed by us, the treatment is in so far completed that the final result is established. In only one case, where an arthrosis deformans existed in the knee joint, a limitation of movement of 20° arose. This patient was granted a pension of 15% for another 6 months. All the others are completely without inconvenience.

A clinical record will demonstrate even better the advantages of the "stabile osteosynthesis" than all these statistics.

During a railroad collison a 38 year old truck driver suffered a transverse fracture of the shaft of the femur slightly above the midpoint and in addition a head injury with a concussion of the brain and a fracture of the left shoulder blade (Ill. 1). On the 7th day after the accident the marrow nailing operation of the fracture of the femur was performed. Three days after the operation the patient began exercises in the bed. A fortnight after the operation he got up without any bandage (Ill. 2) and 45 days after the operation (55 days after the accident) he was released. He has no trouble anymore caused by the fracture of the femur, walks long distances without a cane and without inconvenience, and he can freely move the leg that was injured in all joints (Ill. 3).

This means that the patient is so far as the fracture of the femur is concerned, after a period of not quite 2 months, fully capable of working again. Such a result has never been and will never be obtained with any conservative method.

Regularly, fractures of the shaft of the leg-bone in case of skilled conservative treatment without any inconvenience. In any case, 85.26% of the patients treated by BOEHLER did not obtain a pension. The publications of the workers association of various trades show, however, different findings. BOEHLER for instance found only 17,2% recovering without a partial disability pension in the year of 1910/11. Such findings, however, could not be used as a basis for judgement, for only the results of well directed clinics prove the value of a method.

The economic advantage of the "stabile osteosynthesis" cannot be so great with regard to the final results of leg fractures as compared to the thigh, but it is quite worthwhile in both cases with regard to the duration of the period of treatment in the clinic and the inability for work.

According to the statement of BOEHLER, spiral and "green stick fractures require a hospital treatment of 3 to 4 weeks (constant bandage according to the traction method or repositioning in Plaster of Paris with extension), after this an ambulatory cast will be put on for 5 or 6 weeks. "Young people might in some cases as early as three months be able to return to heavy work. For older people and in cases of severe fractures it lasts about 4 to 6 months.

In comparison to this we offer the clinical report of an apprentice of 16 years of age, when a marrow nailing operation was performed:

We had to deal with a spiral-like fracture of the leg with the separation of a long fragment without displacement (Ill. 4). Two days after the accident he was treated by the "stabile osteosynthesis" according to LUENTSCHER. Because of the separation of the fragment a light Plaster of Paris cast was put on the leg although the fracture was clinically completely firm after the nailing. Within 7 days this cast became loose and was removed. As no pain was mentioned at all during the strain caused by the manipulation and the patient could move the leg freely, no further bandage was put on. 12 days after the accident the patient got up (Ill. 5). 18 days after the accident he was released from the clinic. The joints could be moved completely free. He could walk without any assistance with a cane and without pain. (Ill. 6). 6 weeks after the accident the patient started to work again without any inconvenience. 8 days after the beginning of this work he fell in the dark and suffered a severe hematoma in the ankle joint of the broken leg. He had to stop work again. The fracture itself was in no way disturbed by the fall. It also was not painful. After a further 4 weeks the difficulties of this new accident were healed and the patient was again able to work.

The "stabile osteosynthesis" has therefore resulted in a saving of at least two weeks stay in the hospital and (without the new accident at least 45 work days. But this case also proves the firmness of the marrow nailing, for a refracture would almost certainly have arisen during the second accident without the nailing, if the patient would have been walking in an ambulatory cast within 6 weeks after the first accident.

Transverse fractures of the leg can be treated with a Plaster of Paris cast immediately after the reposition and the patients can be released after being observed a further 8 days with an ambulatory cast which enables them to walk. Generally they are fit for work after 4 to 5 months.

With regard to the treatment in the clinic there will be hardly any saving with the "stabile osteosynthesis". The patients, however, can generally resume work earlier, as the following case shows:

A 38 year old Polish worker was brought in with a transverse fracture in the middle third of the leg.(Ill.7). A "stabile osteosynthesis" was done three days after the accident. No cast was applied. Exercises were started on the third day after the operation. He got up on the seventh day after the operation and walked about. (The patient could have been released a fortnight after the accident. Because of other than medical reasons, however, he remained in the hospital). 20 days after the operation he could move the leg freely and without inconvenience. 31 days after the accident he was released and immediately he resumed his work as a blacksmith in agriculture, although hardly any callus formation could be seen in the X-ray (Ill. 8 and 9). All joints could be freely moved. There was no edema. The "stabile osteosynthesis" therefore accounted for a saving of at least 90 work days in this case.

In cases of a fracture of the shaft of the humerus above the elbow an ambulatory treatment is most often indicated. The abduction cast, necessary after the repositioning, must, however, be left on for four to six weeks and after physiotherapy is still required before the patient can start working again. The "stabile osteosynthesis" spares the patient the rather shapeless and often very disagreeable abduction cast and enables him to use the arm as early as 3 to 4 weeks later.

A school boy of 14 years age with an oblique fracture of the shaft of the arm above the elbow (see Ill. 10) could move his arm without any pain 14 days after the operation and do any sort of work. (Ill. 11 and 12). He was released from the clinic 9 days after the operation.

In this case the "stabile osteosynthesis" saved at least 40 work days. This case is all the more remarkable as we had to deal with a fracture in the distal third of the humerus. As is generally known, difficulties concerning the flexibility of the elbow joint are especially liable to arise in such cases.

The nailing of a fracture of the shaft of the arm above the elbow performed from the upper end brought an especially good success in the case of a boy of 11 years of age (Ill. 13). 10 days after the operation he could move his arm freely and without pain and was released as "healed" (Ill. 14 and 15). Certainly, children often perform astonishing achievements in healing of fractures, but never could such a success have been obtained with a conservative method of treatment.

From several sources the opinion was expressed that some damage of the nourishment of the bone might be caused by the nailing or the formation of callus luxurian. The clinic of Kiel discounts these remarks. I also could not observe any inconvenience in one way or another in more than 140 cases of nailing of closed fractures which I have seen in my own clinic and in the hospitals of the German Air Force.

We certainly are still at the beginning and a warning must be given not ot use the "stabile osteosynthesis" in cases of fractures of long bones without sufficient experience and, equally important, without sufficient equipment. The above mentioned examples indicate unquestionably that it leads to healing and to economic advantages, which make the "stabile osteosynthesis" far superior to all conservative methods of treatment.

S u m m a r y.

"Stabile osteosynthesis" is the fixation of a fracture of a bone by especially shaped metal nails. It eliminates any cast and permits early free movement of the broken limb and weight bearing. In this method the fracture is not exposed. The danger of an infection is thereby materially reduced as compared with the other osteosyntheses. No interrupting of the healing of the fracture has to be feared.

The generally recognized principle of the "stabile osteosynthesis", already known for fractures of the neck of the femur, now becomes available for cases of fractures of the shaft of long bones by the narrow nailing method developed by KUENTSCHER.

In more than 70% of the cases of fractures of the neck of the femur a complete healing was obtained by the "stabile osteosynthesis". The time of hospitalization was reduced by more than 200 days. In all cases of fractures of the femur no difficulty was encountered, the time of residence in the clinic was reduced by more than 200 days and, after 97 days in the longest case, the patients were able to work again. With the conservative method the average time of inability to work amounted at least to 627 days (according to BOEHLER). In cases of fractures of the tibia the time of residence in the hospital and inability to work is considerably reduced. In cases of fractures of the shaft of the arm above the elbow the same saving of time applies and in addition the uncomfortable abduction bandage can be avoided.

The success and economic advantages of the "stabile osteosynthesis" are so outstanding, that to-day (1943) it may be described as the best method of treatment of certain fractures.

Illustration 1
R.O. 35 years old
Transverse fracture of the femur.

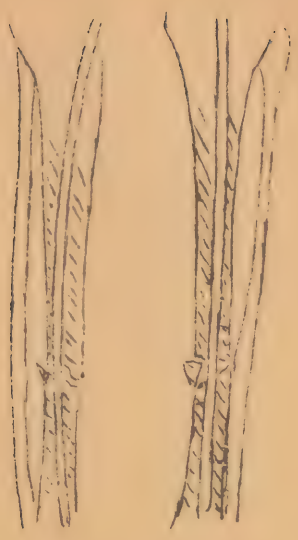


Illustration 2
Same fracture 18 days after operation, 24 days after the accident: good position, good formation of callus. Pat. got up 4 days ago.

Illustration 4
E.H. 16 years old
Spiral fracture of the left tibia with a large fragment broken out.

Illustration 5

Same fracture 13 days after the operation. Pat. got up 2 days ago, without inconvenience.

Illustration 7
J. B. 38 years old.
Transverse fracture of the tibia in the middle third.

Illustration 8
Same fracture 28 days after the operation. Excellent position. No remarkable formation of callus. Pat. got up 21 days ago.

Illustration 10

G.W. 14 years old.
Oblique fracture in the arm above the elbow.

Illustration 11
Same fracture 10 days after the operation.
Arm has been moved since two days.

Illustration 13
K.N. 11 years old.
Transverse fracture in the middle of the right arm above the elbow.

Illustration 14
Same fracture after the nailing starting from the christa tuberculi majoris, ideal position.

(Editors Note: Illustrations 3, 6, 9, 12 and 15 are missing.)

PSEUDARTHROSIS OF THE ARM TREATED BY A MODIFIED MARROW NAIL

by

Privatdozent Dr. RICHARD MAATZ, Kiel

Translation prepared by:

U. S. Naval Technical Unite,Europe,(Medical Section)
Office of Naval Advisor
Office of Military Government (U.S.)

The fate of gun-shot fractures of the upper arm is well-known. I may be permitted to review it in a few sentences. Certainly some of these fractures will heal when they are treated in the usual manner even if there is a loss of substance of the bone. A greater part must pass through a long confinement. Large plaster casts must be worn until the suppuration abates and only a small fistula remains, sustained by sequestra. Recurrence of the inflammation may happen at any time. The sequestra must be removed. Perhaps a cavity in the bone causes further secretion. This will last for months, perhaps years, and during this time the fracture, which is inadequately stabilized by the plaster cast or later on is left without one, becomes a pseudarthrosis or a "new joint". Meanwhile the neighboring joints will become rigid, especially the elbow, and if the radial nerve has been hurt precious time for repairing it is lost. When enough time has passed after the wound closes, the pseudarthrosis may be operated upon. Whether the fragments are united with wire, plates, screws or an implanted chip of bone a new inflammation may arise all too frequently and once more everything will start from the beginning. A great number of the patients are obliged to wear a posthetic apparatus.

Today we have the possibility to interrupt this course. Whatever the condition of the wound may be we unite the freshened ends of the bone, stabilize the fracture by a new method, and we are justified in stating that union is accomplished after a comparatively short time. Incidentally it may be mentioned that we can operate even when the fracture is still in a septic state.

This new method is based on absolutely new ideas. The principle may be described in a few sentences. The ends of the fragments are freshened carefully avoiding any separation of the periosteum from the bone. They are brought into proper apposition without regard for a shortening of the upper arm if necessary and the ends are pressed against each other and stabilized by means of devices introduced into the cavity of the bone.

At the end of the operation the small wound of the bone is covered and protected by the intact thick periosteum. The flesh wound being left open cleans up very fast and is closed after a short time.

It was KUENTSCHER who led us upon this way. At first his nail was intended for closed fractures. On learning that even an infection of the fracture is not dangerous while the nail is lying in the cavity of the bone, we lost our extreme respect for the marrow-cavity. Now we know that the marrow cavity can be treated as we like if only the exterior of the bone is not damaged. HEIM was the first to nail suppurating gun-shot fractures. Other authors followed.

But soon a great disadvantage was noticed, which was first published by HFABLER, even concerning closed fractures of the upper arm. Often the fracture shows a distraction because the tonicity of the muscles of the arm is not sufficient to maintain apposition. By mechanical reasons

the curved nail introduced from the side of the bone is able to prevent this separation but only for the first days (MAATZ). In spite of these conditions a nailed closed fracture unites in most cases. As the tonicity of the muscles in an infected region is materially diminished the separation of the fragments will occur in nearly every case, especially if it is a gun-shot fracture with a loss of substance. It is evident that a suppurating fracture is more likely to turn into a pseudarthrosis.

I also noticed many cases of this kind among fractures nailed in other hospitals or by myself. Among the 17 pseudarthroses of the upper arm I had the occasion to cure by this new method, 7 had already been operated upon before with the medullary nail but without the desired effect.

The development of my presently used method will be demonstrated best by the following case.

Patient Paul M. was injured 31 December 1939. It was an open fracture of the left upper arm near the elbow. Since it had become a pseudarthrosis, it was operated upon in 1941. Subsequently there was a serious inflammation in which the joint of the elbow was involved. The wound closed during 1942, the joint having become stiff while the pseudarthrosis continued. It was in this state the patient was sent to us (Ill.2)

Illustration 1
Line of incision and extent of resection of the fistulating pseudarthrosis.

On 10 November 1943 the ends of the bone were freshened and the pseudarthrosis was nailed with a thick straight nail introduced through the destroyed joint into the elbow. Immediately the inflammation recurred. The nail due to its weight began slipping down out of its bed and the fracture separated.

The nail was not removed but its gliding was stopped by applying an elastic wire fixed in the plaster cast. Moreover the ends of the bone were pressed against each other by rubber strips which bridged over a circular cleft cut into the plaster (Ill.3).

All the wounds closed except a fistula at the place where the nail was projecting like a drain. 4 months afterwards the humerus showed bony union.

Illustration
2a

Illustration
2b

Illustration 2c

Illustration 2d

Illustration 3

Suppurating pseudarthrosis with nail in position and additional plaster-dressing with rubber strips.

This case shows clearly that a fracture resistant to union for a long time may heal finally if only the absolutely necessary conditions are realized namely:

Impossibility of any movement in the fracture no matter how serious an inflammation may take place in the cavity of the bone during the whole time.

This led to the idea of transferring the contracting elements directly into the bone.

At first I used only a simple wire but the first cases proved it to be insufficient. A small area of the ends of the bone will be digested by the suppuration and the cleft thus brought into existence is wide enough to impede bony union.

Moreoever the thin wire cuts through the bone with its curved ends fastened in the corticalis. Therefore, I am now using a spiral spring made of steel which is anchored in the corticalis of both fragments by means of broad hooks. (Ill.4)

Illustration 4
Medullary spiral spring with hooks to be fastened in the corticalis

This is the place to describe how to treate the usual and favorably situated pseudarthrosis of the upper arm. The pseudarthrosis is located in the middle third of the humerus. The ends of the bone are prepared as mentioned in the beginning(Ill. 1).

Because separating the periosteum from the bone at any place is strictly to be avoided, the periosteum must be severed with a scalpel from the surrounding cicatrical tissue round one half of the circumference (Ill. 5a).

This is absolutely necessary because the pseudarthrosis after being cut through with a scalpel must be broken in a right angle direction and in this moment the periosteum adherent to the scarred tissue likely will be stripped from the bone (Ill. 5b).

Illustration 5

Course of resection of the pseudarthrosis.
a. line of incision
b. oblique freshening of the ends of the fragments
c. opening both marrow rooms
d. bone prepared for the introduction of the spring and the nail.
Periosteum shown in black.

Now it is quite possible to prepare the ends of the fragments with a rongeur (LUER). Here it is best to level both ends as this proved to be the most favorable condition for the union to take place (Ill. 5c). Both marrow cavities are opened sufficiently wide with a drill in order to restore the original cavity of the bone (Ill. 5d). More distant from the fracture this cavity must be opened in each fragment by a lateral hole. The wire of the spring is pulled through the proximal fragment in the direction from above to below. Another wire doubled to a loop is introduced from the distal hole near the elbow in the opposite direction (Ill. 6a).

Illustration 6

Introduction of the spring
a. In the upper fragment the wire of the spring is introduced ready to be attached to the wire loop put through the distal fragment.
b. Spring in position

By means of the distal wire which is fastened to the proximal one bearing the spring it is possible to pull the latter through the marrow cavity of the distal fragment (Ill. 6b).

Now the nail may be introduced from the proximal fragment. The open side of the curved nail should at the same time be the concave one as it is necessary to have the spring gliding in the cavity of the nail. Otherwise it may occur that nail and spring will not have room enough in the cavity of the bone. After the fragments are driven together with the nail inside, the spring must be stretched and the end of the wire fastened at the distal hook.

All wounds are left open. The operation is concluded.

Another way of proceeding is necessary when the pseudarthrosis is situated far proximal near the caput humeri. There we have only a very thin corticalis and we must distribute the power of traction of the stretched spring to several places.

We do not use one but several hooks (two or three) which are fastened to different parts of the corticalis. The power of the spring is distributed to the several hooks by means of one place of soft flexible wire drawn through each hook and through the single ear on the spring. In the distal fragment also in these cases one hook is sufficient but the nail has to be introduced from the distal part. It has proved to be most efficient to introduce the nail and the spring from two different holes since the cavity of the bone is too small to give room enough for both on one place.

In such cases it is possible to bring the idea of not manipulating the exterior of the bone to its climax. The holes for the hooks in the upper fragment actually situated close to the fracture must be drilled from the inside of the bone. This is possible because the diameter of the cavity is rather large there. The hooks too may be introduced from the inside.

Illustration 7

Case 10. (see table 1)
State after the operation of a fistulating pseudarthrosis of the upper arm.

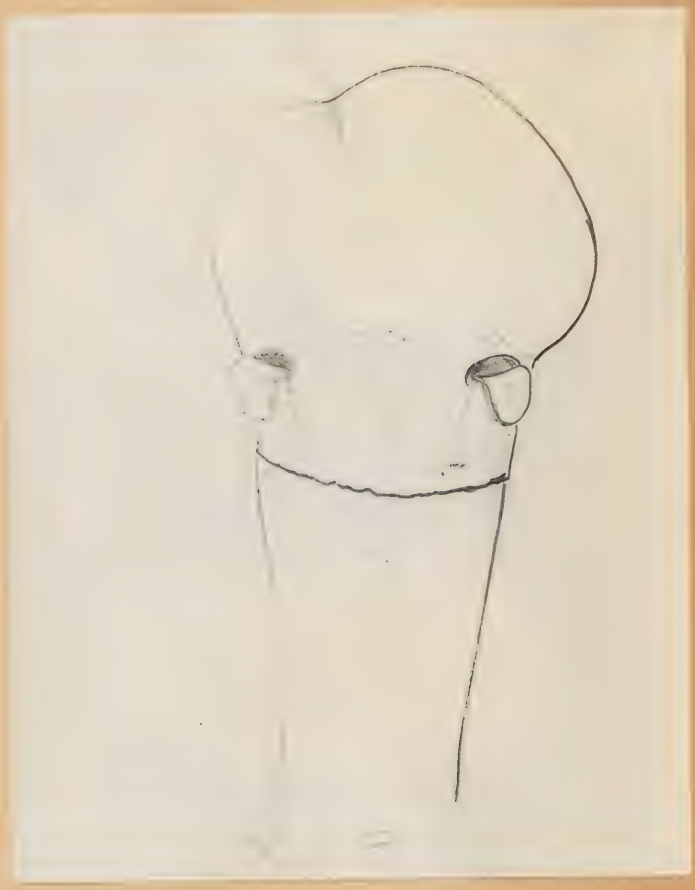


Illustration 8

Resected pseudarthrosis near caput humeri. The spring is fastened in the corticalis of the upper fragment with three hooks.

Illustration 9a

Case 11 (see table 1)

Before the final operation.

Illustration 9b
Condition after operation on 1.3.46 spring and nail in position.

Illustration 9c

Bony union achieved.

In fact this no longer means nailing in its original sense. The bone has grown brittle by the suppuration. It is absolutely necessary that all the holes and cavities in the bone prepared are properly fitted to the nail, the spring and the hooks. This may rather be called (montage) plastic restoration.

Therefore and in consideration of the fact that healing of a pseudarthrosis of the upper arm is difficult to obtain, I think it most commendable to support the healing by an additional plaster cast in abduction.

Of course each case has its peculiarities as the following example will show. It is not always possible or necessary to bevel the bone ends. Sciagraph picture 10 shows a pseudarthrosis with a far greater diameter of the upper fragment than of the lower one due to four antecedent operations with resection. Therefore it seemed to fit the lower fragment into the upper one.

Another case of pseudarthrosis was characterized by a thinning out of the proximal fragment whilst the distal fragment was split up like a fork.

Here the upper fragment was fitted into the lower one after freshening only the surfaces which were to be brought into apposition.

Sciagraph picture 12 shows a loss of substance of more than 10 centimeters. Therefore an autoplastic chip of bone was implanted and the pseudarthrosis was nailed. The chip did not heal in and therefore further shortening of the arm became necessary. Bony union was obtained by applying nail and spring.

Illustration 10a

Case 13 (see table 1)

a-c 56 months old pseudarthrosis after three operations: wire cerclage, nailing with bone-chip and nailing.

Illustration 10b

Illustration 10c

Illustration $10d_1$

Illustration $10d_{1 \& 2}$

The ends of the fragments are not freshened obliquely but are fitted into each other.

Illustration $10d_2$

Illustration 10e

Pseudarthrosis healed one hook embedded in bone.

In the case of picture 13 a separation of the bones by means of a simple wire in addition to the nail was tried in vain.

Up until now I have operated 17 patients in this manner. The importance of this new way of curing the pseudarthrosis of the upper arm is shown by the fact that in all cases bony union was achieved. How much it proved to be beneficial to the bone is shown by the fact that we did not observe sequestra in any case. The size of the callus will depend on the amount of trauma to the periosteum and on the amount of displacement and of motion during the process of repair. All the latest cases operated carefully with technical exactness are showing effective bony union without the development of the least callus tumor (Ill. 14).

The following table gives a survey:

Results of the operations upon the upper arm.

Nr.	Name and age of the patient	Previous operations	Interval between injury & final operation	Final operation: Condition	Final operation: Date	Shortening of the upper-arm	Healed after: Soft tissue wounds	Healed after: Bone	Removal of nail after	Remarks
1	Sie. 42 years	none	4 weeks	suppurating shot-fracture with loss of substance	March 1944	5 centimeters	2 weeks	3 months	10 months	-
2	J., Hans 24 years	none	2 months	septic state, shot-fracture in the middle	8.VI. 1945	2 centimeter	3 months	3 months	3 months	Sudeck atrophy
3	R., Otto 35 years	nailing	8 weeks	near the elbow, nail in position, suppurat. longitudinal separat.	16.4. 1945	2 centimeter	6 weeks except 2 small fist.	3 months	8 months	-
4	G., Walter 29 years	none	6 months	fistulating pseudarthr. with loss of substance in the lower third.	3.7. 1945	centimeter	3½ months except 1 small fist.	3 months	dismissed with nail in posit.	-
5	H., Hans 38 years	none	23 months	fistulating pseudarthrosis in the middle.	14.7. 1945	centimeter	5 months except a more strongly supp. fist.	4 months	9 months	-
6	K., Franz 39 years	none	4 months	fistulating pseudarthr. with secuestrum in the lower third.	23.7 1945	centimeter	2 months except 2 small fist.	3 months	8 months	paralysis of nervus radialis after injury
7	K., Franz 32 years	nailing and wire suture	5 months	septic.state, suppur. pseudarthr. near the elbow, nail in position	12.9. 1945	centimeter	1 month except 1 fist.	3½ months	6 months	par. of N.rad. after injury
8	F., Johannes 22 years	nailing	18 months	fistulating pseudarthr. with loss of substance nail in position, middle of the humerus	12.9 1945	centimeter	2 months	3 months	7 months	par. of N.rad. after injury
9	D., Heinrich 36 years	implanting of bone-chip & nailing	14 months	nail in position, wounds recently closed	24.10. 1945	3 centimet.	3 weeks	3 months	7 months	-
10	K., Werner 21 years	none	12 months	fistulating pseudarthr. in the lower third	26.11. 1945	centimeter	4 months	3 months	6 months	par. of N.rad. after injury
11	H., Franz 34 years	wire cerclage	15 months	fistulating pseudarthr. with loss of substance near the caput humeri	1.3. 1946	3 centimeter	7 weeks	3 months	5 months	par. of N.rad. after injury
12	H., Otto 42 years	none	11 months	pseudarthrosis with loss of substance in the upper third	16.3. 1946	3 centimeter	8 days	2½ months	5 months	-
13	W., Paul 34 years	1) wire-cerclage 2) nail & chip 3) nailing	56 months	Pseud. near caput hum. nail in position wounds closed	1.4. 1946	12 centim.	2 weeks	2 months	5 months	-
14	A., Erwin 25 years	none	14 months	fistulat. pseud. with seq. in the upper third	1.4. 1946	5 centimeter	6 weeks	3 months	6 months	-
15	G., Walter 23 years	nailing & chip of bone	17 months	supp. pseud. with seq. nail in position	14.5.46	4 centimeter	2 months	2½ months	5 months	-
16	K., Heinz 30 years	nailing & spring	13 months	fistulat. pseud. near caput humeri, nail in position	14.5. 1946	7 centimeter	6 weeks except one small fist.	2 months	7 months	-
17	G., Helmuth 20 years	nailing	15 months	pseud. after removal of the nail in Aug. 45	24.4. 1946	3 centimeter	3 weeks	2 months	4 months	The reason for the considerable shorten. was the loss of sub. of the N. rad.

TABLE 1

Illustration 11

Case 4 (see table #1) here too the ends of the fragments are not freshened obliquely but are fitted into each other.

Illustration 12 a & b

a. 6 months old pseudarthrosis of the upper arm with great loss of substance.
b. state after nailing and implanting of a bone-chip without success.

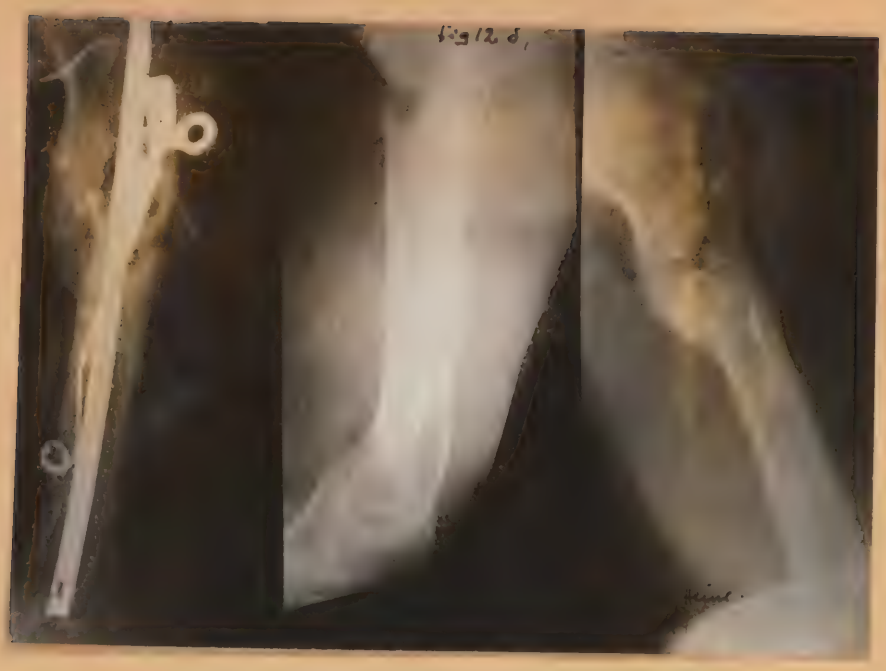


Illustration 12 c & d

c. Nail and spring in position
d. Bony union after 3 months removal of the nail after 7 months.

The small fistulae often remaining as long as the nail is in position, all close without exception as soon as the nail is removed.

Illustration 13a
Case 8 (see table 1)
Gun-shot fracture pseudarthrosis with loss of substance.

Illustration 13 $b_{1 \& 2}$

State aft r introduction of nail and simple .irc 8 weeks previously longitudinal separation .

Illustration 13 $c_{1 \& 2}$

Nail and spring in position bony union after 3 months.

Illustration 13d

Removal of nail and spring
after 7 months.

Illustration 14 1 & 2

Scanty development of callus with effective bony union after proper resection of the pseudarthrosis 3 months previously.

The Pseudarthrosis of the Forearm.

The same principle is applied to the pseudarthrosis of the forearm, whether one or two bones be injured. The healing of this pseudarthrosis is obtained by other methods with certainty but very often they need a long period of treatment. In many of these cases the nailing has not proved to be efficient. The tendency to form callus in these bones is but slight and if there is a gap between the fragments of the suppurating fracture it will be found very often that though the bone is well stabilized by the nail nevertheless it is not able to produce a bony union. Here too we can interrupt the long period of treatment at an early stage by operating upon the pseudarthrosis using the same method as described for the upper arm.

The pseudarthroses of the forearm show many varieties dependent on their location.

The operation is more difficult than on the upper arm since we have bones united by the membrana interossea which renders the preparation of the ends of the fragments more difficult. Here it is of greatest importance to do no damage to the periosteum in order to avoid the danger of the development of a ring-shaped secuestrum or of a bridge callus. It is absolutely necessary to shorten both bones correspondingly. The medullary cavity in most cases is rather narrow and filled up with dense osseous tissue in the neighborhood of the fracture. Thus the bed for the nail and the spring must be prepared with the greatest care. Therefore we use a "marrow-drill". Many technical resources may be required in order to guarantee the uncomplicated conduct of the operation. This is not the place to describe all these in details. Only one bone, namely the ulna is treated with the spiral spring. This has proved to be sufficient.

Moreover the radius is not well suited for the fastening by the spring. In the ulna it can be attached to the proximal end of the nail. The ulna-nail is flared at its proximal end for several reasons:

1. Small diameter nails have proven not be firm enough as we learned from numerous cases which have been published, the simple nail for the forearm having broken or bent.

2. There must be room enough for the spring in the cavity of the nail.

3. The increasing thickness of the nail towards its proximal end prevents it being drawn in the distal direction by the power of the spring.

The wire of the spring is fastened to the distal fragment in the usual way but distal to the point of the nail because there is not room enough for both hook and nail at the same place. The arrangement of the nail and the spring may be seen in Ill. 15.

Illustration 15

Position of nail and spring in the ulna.

Illustration 16 a 1 & 2

Comminuted gun-shot fracture of the radius (March 1945) with failure of bony union.

Illustration 16b

State after freshening of the pseudarthrosis and shortening of the ulna (Feb. 46). Both bones are nailed. Bony union is not achieved. Pseudarthrosis of the ulna.

Illustration 16 d

State after operation with nail and spring (Apr. 46)

Illustration 16 $e_{1\&2}$

Healed with bony union after 8 weeks. Nail and spring are removed.

Results of the operation upon the fore-arm:

Nr.	Name and age of the patient	Previous operations	Interval between injury and final operation	Final Operation: Condition	Final Operation: Date	Shortening of the Forearm	Healed after: Soft tissue	Healed after: Bone	Removal of the nail after:	Remarks
1	Z., Julius 28 years	nailing	11 months	recently healed fistula	16.3.46	4 centim.	2 months	2 months	3 months	-
2	M., Heinz 23 years	none	12 months	pseudarthrosis of radius and ulna	8.3. 1946	4 centim.	3 months	3 months	5 months	-
3	H., Hildegard 20 years	nailing	8½ months	fistulating pseud. of radius and ulna	15.5. 1946	3 centim.	-	-	-	-
4	F., Erich 32 years	nailing	27 months	fistulating pseudarthros. of the ulna	13. 4. 1946	5 centim.	4 months	3 months	5 months	*
5	M., Paul 30 years	Lane-plates (radius) & chip of bone transplanted (ulna)	16 months	Pseudarthrosis of radius and ulna	25.6. 1946	3 centim.	8 days	2 months	5 months	paralysis of Nervus radialis
6	B., Walter 31 years	1. nailing & chip of bone 2. nailing & marrow-spr.	25 months	fistulating pseudarthrosis of radius and ulna.	20.7.46	4 centim.	1 month	2½ months	4 months	-
7	K., Alfred 20 years	none	16 months	New joint of radius and ulna near the wrist	27.7. 1946	1 centim.	14 days	2 months	3½ months	spring without nail in radius and ulna.

TABLE 2

TABLE 2

I have operated upon five cases with the marrow spring. All cases had previously been treated with the nail but the pseudathroses had not been cured. By means of the spring bony union was achieved without exception.

The following table gives a survey.

L I T E R A T U R E

BOEHLER ..... Zschr.Orthop.u.Grenzgeb. 75.Bd 4.H. 1944

HAEBLER ..... Zbl.Chir. 1943, 734

HEIM ..... Mil. Arzt 1943 H.3

KUENTSCHER..... Zbl. Chir. 1941, 1

MAATZ ..... Zbl. Chir. 1943, 1260

" ..... Chir. 1943 H.9